JOURNAL

OF THE

New England Water Works Association.

VOLUME XIX.

1905.

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION,

715 Tremont Temple, Boston, Mass.

The Fort Hill Press
SAMUEL USHER
176 TO 184 HIGH STREET
BOSTON, MASS.

INDEX.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XIX. March, 1905. No. 1.

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HYDRAULIC COMPRESSED AIR IN CONNECTICUT.

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[*Read September 15, 1904.*]

The use of compressed air for the development and transmission of power is very old. On the walls of a tomb in Egypt, there is a representation of two men standing on leather bags of air, alternately pressing them down with their feet, to produce a blast for a furnace. The ancients used compressed air in blow guns, in forming jets for fountains, in blasts for forges, and for other purposes. Papin used compressed air for forwarding packages, in tubes, two hundred years ago in France. It has long been used in diving-bells and in tunneling. Brunel used it in tunneling under the Thames in 1825. In 1849 compression was proposed to be performed in stages, with inter-coolers between each stage, to get 750 pounds pressure for locomotives.

The first successful use of compressed air for the transmission of power, as now known and used, was at the Mt. Cenis tunnel in 1861, where air was compressed to five atmospheres by two methods, one being by pumps or rams in which water was the piston, but though the air came in contact with the water, it was only slightly cooled, at the surface of the water and around the walls of the cylinders.

About 1870, at Vienna, and later in Paris, a system was installed for working and regulating a great number of clocks by the use of compressed air from a central station. This soon developed into an extremely important system of power transmission. Paris

now has great compressor plants supplying 25 000 horse-power, and more than 50 miles of distribution pipes, supplying air at 75 pounds pressure to thousands of customers, who use it for every purpose, from cooling beer or dusting furniture, to running electric light dynamos. A little stove, with a common kerosene lamp, is used to heat the air before use in the small motors. The motors in use range in size from one tenth of a horse-power to 150 horse-power, most of them being less than one horse-power. They are started or stopped by simply opening or closing a valve.

The cooling of the air while it is being compressed, and reheating it for use in engines, are matters of great importance. If the air is cooled as it is being compressed, the volume will be much smaller, under a given pressure, than the same amount of air would occupy if allowed to retain the heat caused by compression. Then again, if the compressed air is heated just as it enters the engine, the volume will be much increased, while the same pressure is maintained. The economy in using coal for developing power in this way is so great that four or five times as much power can be secured from a pound of coal, through reheating the air, as can be secured through making steam. The reason for this is chiefly that a great portion of the heat of the coal is absorbed, and becomes latent and ineffective, in turning water from the fluid to the gaseous form in making steam power, and no such loss occurs in expanding the air and so increasing *its* power. It is feasible to increase the power of an air engine fifty per cent., by such reheating of the air.

The method of compressing air by entraining it in water, and causing it to pass down in the water to a great depth, so that it is subjected to a great weight of this incompressible fluid, is an ideal one. In this way the air is compressed isothermally, the heat of compression being absorbed steadily by the surrounding water, and the air is, therefore, delivered to the pipe line as cool as the water through which it has passed. The compressed air is also drier, or will be when used in the motor, than the atmospheric air from which it was withdrawn. This comes from the fact that the surrounding water absorbs the moisture precipitated from the air as its capacity to hold water is diminished under compression. A dry, cool air is thus secured for the dis-

tribution system, comparatively free from the danger of freezing on its way to the motor, or on its expansion in or from the motor. Where there is no moisture to freeze, there is no freezing.

I have been asked to describe to you, briefly, some of the features of a recent installation of a plant for the hydraulic compression of air, to be transmitted a few miles for use in the development of power. This plant is on the Quinebaug River, just above its junction with the Shetucket River in Connecticut, and alongside the track of the Norwich & Worcester Railroad, near the point where the track passes through a tunnel; which fact has given the name of the tunnel privilege to the falls which have been utilized by the establishment of this plant. At this point the river passes through a narrow, rocky gorge, and to utilize the full fall available, the surface of the water above the dam must be brought within a few feet of the level of the track. This condition made necessary the adoption of devices for limiting the height to which flood water would rise over the proposed dam, so as not to overflow the railroad track. For this purpose the length of overflow on the dam was increased, so far as practicable, by laying the plan of the dam somewhat in the form of the letter Z, thus about doubling the length of the overflow of the dam, and of course, correspondingly decreasing the thickness of the sheet of freshet water passing over it. Another device consisted in the establishment of automatic flashboards, so designed that with the water at the normal stage of the river, the flashboards would retain their position and hold the water to the full allowable height, but upon the increase in the discharge of the river, and consequent rise of the surface above the level of the flashboards, they would turn to a nearly horizontal position and so open a passage for the water to a level between three and four feet lower than the top of the flashboards when in their normal positions.

In the plan, Fig. 1, the positions of the screen, gates, and compressor tank are to be seen upon the left bank of the river. The shore and the bed of the river at this point are of ledge, but the bed of the stream had been filled in places to a considerable depth by bowlders unattached, though compactly placed, and it was not considered safe to form the dam upon any other material than the solid ledge in place. Laborious and expensive excava-

tion was necessary in some places to uncover the ledge, and at points excavation was made considerably below sea level.

To protect the men from inundation by the water in the river, coffer dams were erected, covering successively different portions of the excavation, and these coffer dams were generally formed of square-edged planks, set vertically and supported by timber cribs.

The dam is formed of what is called Cyclopean concrete, consisting of Portland cement mortar with stone, gravel, and sand

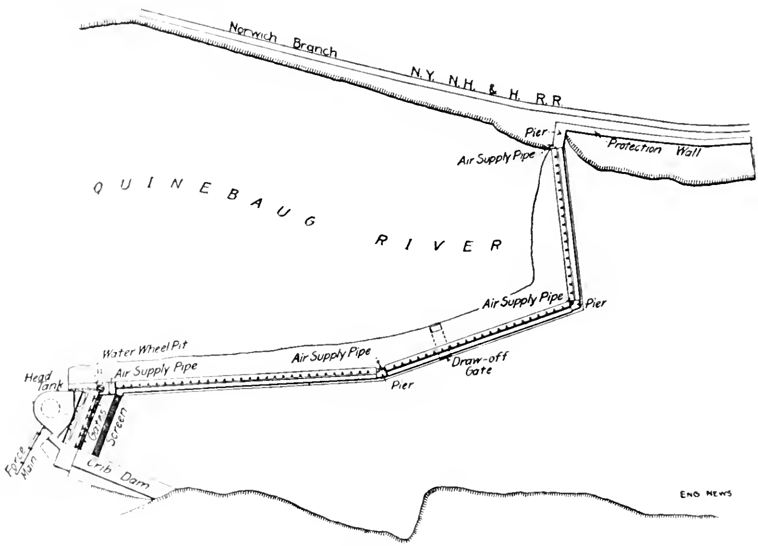


FIG. 1.

of varying sizes up to those as heavy as could be handled by the derrick. These materials were so mixed that no two pieces of large size would touch each other, but every piece was surrounded and encased in materials of less size down to the fine powder of the Portland cement. These materials were so placed as to form a dam of the necessary stability, and the form of section for this purpose, as adopted, is shown in Fig. 2.

The materials, while the cement was setting, were held in position by forms of plank set to enclose the dam and removed when

FIG. 1. SHOWING FORMS AND CHARACTER OF CONCRETE.

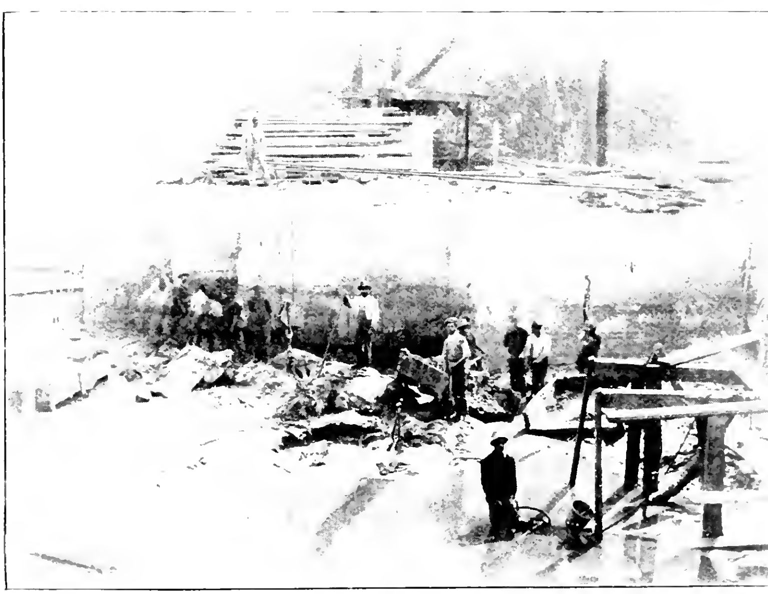


FIG. 2. JUNCTION OF SECTIONS OF THE DAM.

the mortar had set sufficiently for that purpose. The positions of some of these enclosing forms, together with the character of materials used, may be seen in Plate I, Fig. 1.

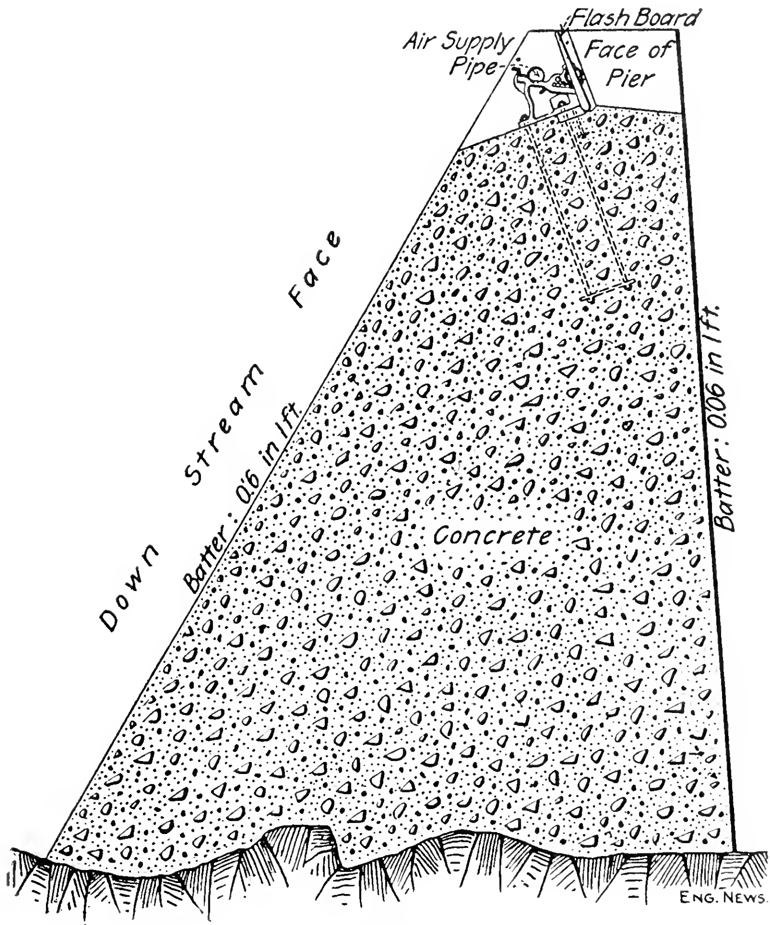


FIG. 2.

When the concrete structure had arrived at a sufficient elevation to form the floor of the inlet to the compressor, the surface was carefully leveled and floated and troweled to the right ele-

vation. This was at the lower end of the dam on the left bank of the river.

It was necessary to control the access of water from the river to the head tank of the compressor, and for this purpose substantial mill gates were used. These gates control three openings, eleven feet wide and eleven feet high each. These gates can be operated by a small water wheel set in the head wall of the dam.

In constructing the dam it was necessary to put it in in sections, so that the river might be diverted and passed through or over one section while another section was being constructed. In making a junction of a new section with one which had been previously built, care was taken to lock the two together as securely as possible to obtain a tight connection and one which would have the greatest available strength. The surface of a section, partially constructed, at one end of an angle in the dam, and where preparations were making to begin the construction of a new section, is shown in Plate I, Fig. 2.

The flashboards, designed to open and furnish additional opportunity for storm water to escape, are substantial structures, formed of white oak and steel, in sections six feet in length and three feet seven inches in height. Efforts have long been made to construct automatic, or movable dams, which would open when the quantity of water flowing in the river required it, and would, of themselves, close again when the water in the river had returned to a safe level. Nearly seventy years ago a dam was formed of a series of shutters, in France, with the axis so placed that the pressure of water above and below would be equal when the level of water in the pond stood at the top of the flashboards; that is, the axis was one third the height above the bottom of the flashboards. When the water rose above this point, the pressure became unequal and was greatest above the axis. When the dam opened and relieved the pond, it was found that the dam would not set itself up again against the stream, after having once opened, and therefore the automatic action sought for had not been accomplished. In the present instance the flashboards are so hung that they do automatically, and gradually, open and close as the water rises above the crest or falls to a level with it. Some details of these flashboards are shown in Fig. 3, and a view

of the top of the dam with flashboards wedged in various positions is shown in Plate II, Fig. 1. When the water in the pond is at its normal level, and the flashboards are in their normal positions, the point of bearing on the axis is at one third the height of the flashboards above the bottom, or at the center of the pressure of the water. The lower portion of the flashboard is so weighted that the center of gravity of the moving parts is below the point of bearing, and upstream from the perpendicular line drawn through the point of bearing. The flashboard is hung on a rolling hanger, confined in place, having such a form that as the height of water against the dam increases and tips the flash-

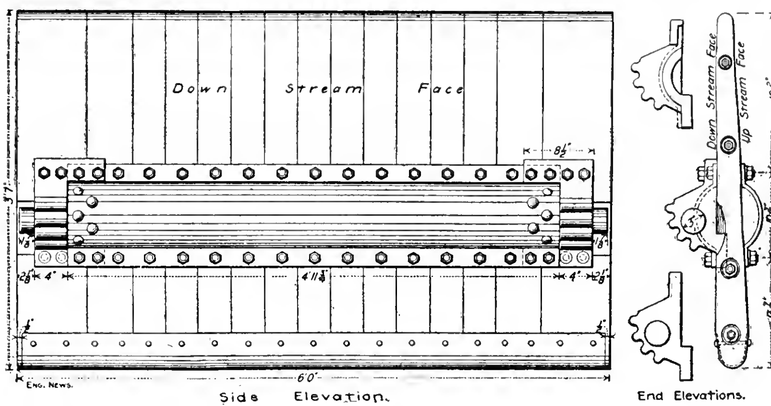


FIG. 3.

board, the resisting point of the flashboard rises to meet the new center of pressure and the resultant forces produced by the moving water. In its new position, the resistance of the flashboard to motion, and the forces tending to move it, are in equilibrium so long as there is no change in the volume of water flowing, but as this volume changes, the flashboard assumes a new position, either wider or less open, as the quantity of water continues to increase or decrease. This result arises from a combination of overbalancing weight, in the lower part of the flashboard, aided by an equalization of the areas above and below the point of bearing, on which the forces, caused by the moving water, act when the dam is open. The device is simple and massive. The

frames on which the hangers roll and to which they are confined are well anchored to the masonry and are so constructed as to furnish a stop to the flashboard when it is fully open, to prevent the possibility of its passing beyond a point where it could be favorably acted upon, as the level of the water in the river retreats to its normal height. These flashboards have now gone through several winters, with their freshets, accompanied by ice, logs or uprooted trees or other floating matter and have withstood all this without resulting injury, and they have worked satisfactorily in allowing increased opportunity for the escape of freshet water and in withholding the pond level to its normal height.

Having now brought the water to such an elevation that we can avail of a sufficient fall between its surface and the tail water we will proceed to a further consideration of the Norwich compressor plant with the available fall of 22 feet. In order to compress the air to a sufficient degree by submitting it to the weight of a head of water, a shaft was sunk vertically to a depth 208 feet below the bed of the river or 215 feet below the surface of the tail water, and at the bottom this shaft was enlarged into a chamber to contain the air separator. The shaft is 24 feet in diameter and the chamber at the bottom is 52 feet in diameter. Opening out of the chamber at the bottom is an air reservoir regulator, in the form of a tunnel from 15 to 20 feet in height and 18 feet in width and having a length of about 100 feet. Suspended in the middle of the shaft is a downflow pipe of steel, about 14 feet in diameter, connected at the top with the head tank, through which water is received from above the dam, and at the bottom with a separator chamber. This chamber is surmounted by an air reservoir, to contain the compressed air when separated from the water in which it had been entrained, and with which it had been carried to the bottom of the shaft. From the air reservoir over the separator, a 16-inch leading main rises to the surface, and is laid toward Norwich, conveying air under about 90 pounds pressure for the use of the engines at the several establishments employing it for power. A general idea of the shaft, down-flow pipe, separator, leading main, etc., can be obtained from Fig. 4.

In sinking this shaft through the ledge, below the bed of the

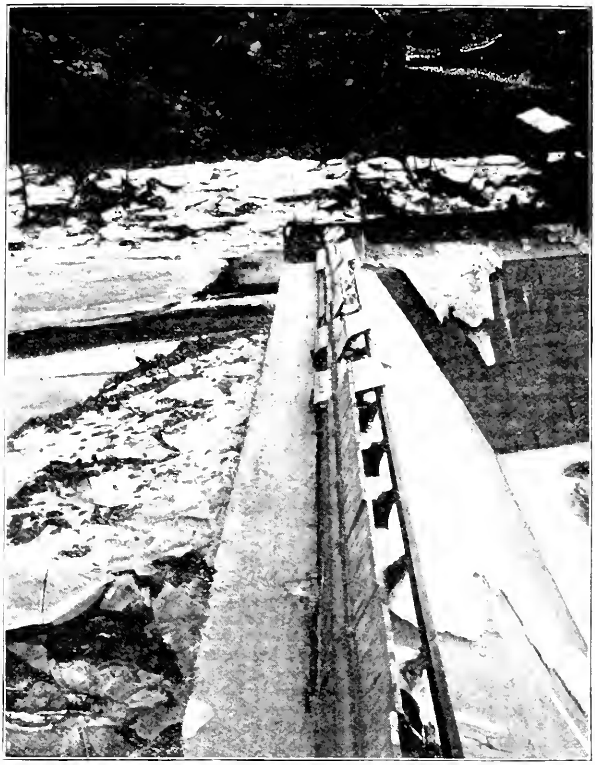
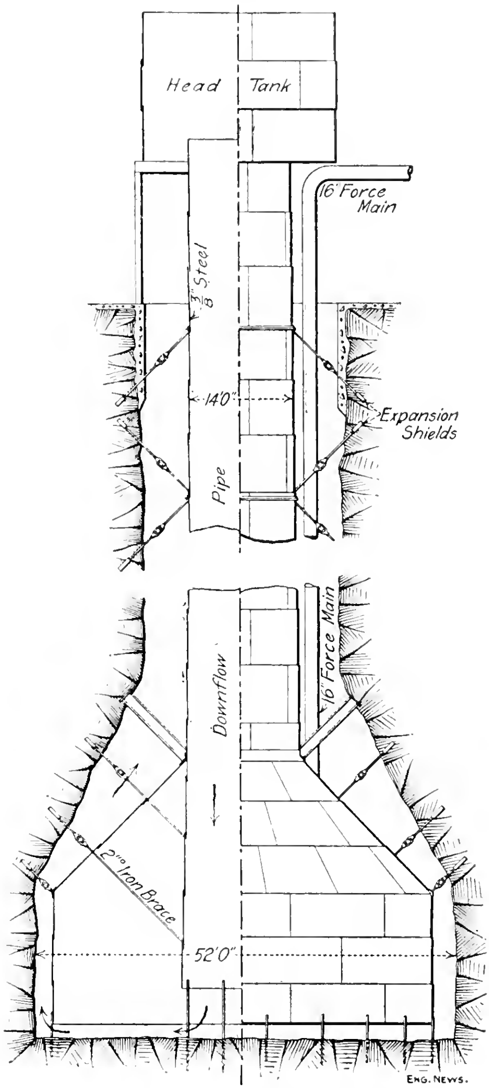


FIG. 1. VIEW OF CREST OF DAM, SHOWING AUTOMATIC FLUSHBOARDS.

FIG. 2. VISIBLE PORTION OF COMPRESSOR IN ACTION.

river, it was found that the upper portion was not sufficiently strong to serve for the permanent walls of the shaft, and for a



½ Section. ½ Elevation.

Fig. 4.

considerable distance the excavation was lined with concrete, formed by filling a space between curbing, inserted for the purpose, and the surface of the ledge as excavated.

After the shaft and its appurtenances had been completed, the erection of the head tank, downflow pipe, and separator, formed of steel, was proceeded with. During this time, the flow of the river, at whatever stage, was passed over the dam, or through a sluiceway.

Plate III, Fig. 1, is a view of the head wall, with a portion of the dam, looking diagonally down-stream, during the construction of the separator.

After the steel work had been completed, all the false works and accessories were removed, and water was turned through the apparatus.

When the compressor is in full operation, entraining the air and supplying it to the air chamber and leading main, the collection of air may be more rapid than its withdrawal for use in engines, or for other purposes. To avoid the disturbance which would be likely to occur if the accumulated volume in the air chamber should force the line of separation between the air and water below the bottom of the downflow pipe, and thus allow of an eruption of air through the downflow pipe and head piece, provision is made for a blow-off, or escape of air to the atmosphere, through a blow-off pipe, having an aperture at the bottom higher than the level of the bottom of the downflow pipe, and through this aperture the excess of air supplied to the separator may escape, before the water line in the air reservoir is carried low enough to cause damage. A view of the entire plant, taken while this escape pipe was in operation and blowing off a surplus of air mixed with water, is shown in Plate III, Fig. 2. When this blow-off pipe was first set in position it was turned so as to discharge nearly at right angles across the river, and it was found that the air and water sometimes escaped with such force that it would drench a passenger train passing over the track. The direction of the pipe was then changed so as to discharge diagonally down the river, as now represented, and where it could do no harm.

The process of entraining the air to the separator before its pas-

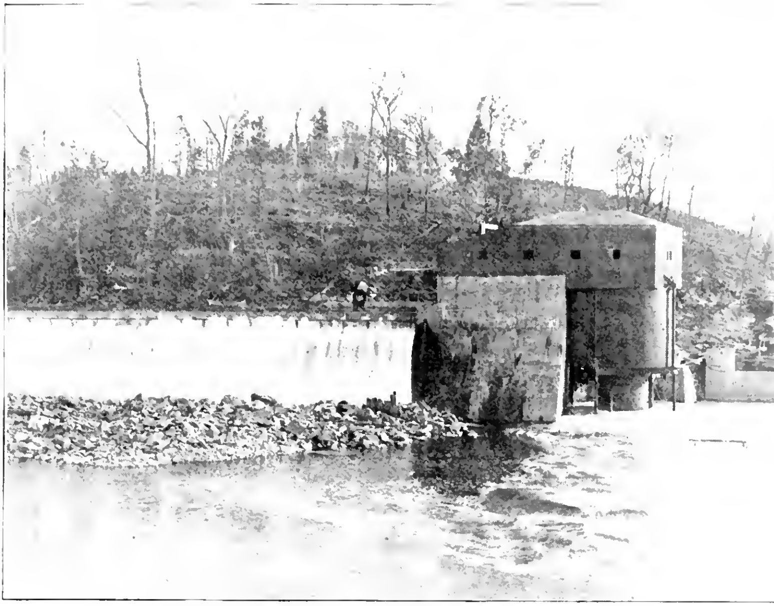


Fig. 1. View of Portion of Dam-Compressor under Construction.

Fig. 2. Blow-off in Operation.

sage with water through the compressor is accomplished by submerging orifices, or air pipes, below or in contact with the surface of the flowing water; such apertures or pipes having proper channels for a free communication with the outer air. The air being in contact with the flowing water is entrained by it, and a partial vacuum being caused thereby, a sufficient pressure is induced to cause a free flow of the outer air through its proper channels to the water. Having been entrained there, at the ordinary atmospheric pressure, the air is carried down in bubbles with the water, and is steadily compressed as the depth of the water increases until, as in this case, it reaches a pressure of about seven atmospheres. Having escaped from the water by floating out of it as the water passes slowly through the separator, it retains, in the air chamber, the pressure due to the weight of the column of water having the height equal to the difference in level between the tail water escaping from the apparatus and the line of separation in the air chamber between the accumulated air and the water out of which that air has floated.

The volume of air which can be carried down with water depends somewhat upon the fall, or the difference of level between the pond water and the surface of the tail water. The greater that difference of level, within reasonable limits, the greater the volume of air which can be carried down with water. In this case, apparently the volume of air is about one third that of the volume of water passing through the apparatus. The combined volume, formed of a mixture of air and water, is of course lighter than a column of solid water, and the aërated column cannot be quite so much *longer* than the solid water column as is represented by the amount of the fall, because a certain amount of force, represented by a portion of the fall, is necessary to cause the mixture of air and water to flow through the separator. I know of no experiments bearing directly upon this matter, but it seems probable that a limit of the volume of air which could be entrained and carried down by a surrounding volume of water, would be reached when the aërated column is about fifty feet longer than the solid water column.

There are various means of measuring the amount of air which may be supplied from a given source, the most satisfactory of

which probably is to pass it through an air meter, having the usual recording attachment operated by clockwork. Various observations have been made upon the amount of air which would pass through an orifice, shaped approximately like the contracted vein formed when a fluid passes under pressure through an aperture in a thin plate. The volume, or weight, of air in pounds per second, may be ascertained, with reasonable accuracy, by taking the area of a circular orifice of this form, in square inches, and multiplying that by the *absolute* pressure, in pounds per square inch, entering the orifice, divided by the square root of the *absolute* temperature, in degrees Fahrenheit, and the whole multiplied by a coefficient varying somewhat with the area of the orifice. For an orifice of one inch diameter the coefficient may be taken at .53.

It is of great importance that the pipes leading the compressed air from the source of supply to the point of use shall be tight, and it is much more difficult to secure such tightness with air than it is with water, or even with steam. Cast iron as a material for such pipes has been very successfully used, but if the joints have been formed in one piece with the pipe, they cannot be successfully made tight by calking with lead, in the manner found to be safe in conveying water.

The joint most extensively used in Paris, and found to be satisfactory there, is formed upon cast-iron pipes having a plain spigot at each end; having brought two pieces of pipe together, place over the joint so formed a short sleeve, nearly fitting the pipe, and long enough to fully cover the joint under such variation of position as may arise in practice. Against each end of this sleeve is placed a rubber ring or gasket, and these rubber rings may be pinched against the ends of the sleeve by other properly formed sleeves or hubs, encircling the pipe and having flanges through which bolts may pass, the hubs being drawn toward each other by nuts on the bolts, thus squeezing the rubber ring between the hub, the sleeve, and the pipe. It is necessary to select a kind of rubber well adapted to this service, in order to secure a permanently tight joint, but with materials properly selected and properly applied, the leakage has been found to be so small that it may be neglected in estimating the amount of air which may be delivered from a distribution system.

In cases where it is desired to substitute another form of power in works where steam engines have been used, compressed air has a great advantage over electricity, in the matter of economy. It is not necessary with air, as it is with electricity, to install new motors at the works, but the engines which have been previously used with steam are well adapted for use with compressed air, thus avoiding considerable expense which would be necessary for electric motors.

In Magog, Canada, I inspected the operation of a plant where air had been compressed by water, in a manner similar to that in operation at Norwich, and where a number of engines were running to drive printing presses for printing cloth. I asked the machinist if there was any special trouble in substituting air for steam in an ordinary engine. He took me into the machine shop, where an engine was driving the machines, and operated by steam. A connection had been made to this engine from the air compressor, and two pipes, one leading steam and one leading compressed air to the engine cylinder, lay side by side. The machinist took hold of the steam valve with one hand, and the air valve with the other hand, and gradually closed the steam valve and opened the air valve, until the engine was running entirely with compressed air instead of with steam. After running a few minutes in this way he reversed the process, gradually closing the air valve and opening the steam valve, until the machinery was being again driven entirely by steam power. Both operations were performed without any apparent change in the running of the lathes and planers, or other machinery, and it is probable that no machinist in the shop knew that any change in the power had been made. The only disturbance during the entire operation, that I noticed, was a slight sound of thumping in the engine, when the air was shut off and the steam re-introduced, probably caused by the condensation of a small amount of steam when passing into the cylinder, which had been cooled by the compressed air. Any non-condensing steam engine seems to be well adapted to driving by compressed air, whether used at full stroke or under cut-off, the substitution of air for steam being made without changing the engine.

I have before mentioned that a great economy in the use of

compressed air for power purposes may be secured by reheating the air just as it enters the engine. An economy of from 30 to 40 per cent. is sometimes possible in this way.

Compressed air has a great advantage, when it is desired to use transmitted power intermittently, and with periods of non-use intervening with periods of use. There is no loss in maintaining this power when it is not in use. There is no leakage like the leakage of electricity. There is no reduction of pressure like that caused by the condensation of steam. The whole power is available whether used continuously or at intervals.

Each method of producing or transmitting power, whether by steam, or gas, or oil, or electricity, or compressed air, has advantages of its own under favoring conditions, but the use and value of compressed air seems heretofore to have been but partially known and poorly appreciated. I quote from Richards: "The use of compressed air has been slow of development, and is still backward, but at this writing I am able to enumerate two hundred distinct and established uses of compressed air, and in more than ninety per cent. of those uses electricity is absolutely inapplicable, and in the remainder, which form a field more or less open to other agencies besides either air or electricity, the air generally has the advantage."

In the Norwich plant the production of compressed air is very uniform and the pressure is held steadily at about ninety pounds while the compressor is in operation. A card from the pressure recording gage shows that the pressure for the whole twenty-four hours varies only about two pounds, standing at just ninety pounds nearly all the time. The water, when this card was taken, was turned through the compressor, begininng at a little before five o'clock in the morning, and in about ten minutes the card represented the full amount required to carry the pressure from that existing through the night to the ninety pounds which is the standard pressure. At about fifteen to twenty minutes after five in the morning, the distribution pipes are blown off, to free them from any possible moisture which may have gathered over night, and this operation is shown by the reduction in pressure of about one pound. This pressure is, however, restored in about ten minutes and from that time to midnight the full pressure of ninety pounds

is uniformly maintained. After that time until 4.45 in the morning the pressure shows a gradual reduction of about two pounds, but I am informed that this is not probably the result of leakage, but that small amounts of air are drawn, for various purposes, during that period in the night. Daily cards are taken, the change from one card to another being made at about nine o'clock in the morning.

The air delivered from the Norwich plant is in use in over forty engines, and its employment is a source of great satisfaction to the men who formerly were obliged to reach the works by 4 or 4.30 in the morning, to get up steam and have everything ready to start at 7, and who now have the comfort of waiting until a few minutes before 7. Upon arrival, they simply turn a valve and the machinery starts off at full speed.

DISCUSSION.

MR. EDWARD ATKINSON. I should like to ask if this power is sold.

MR. SHEDD. It is sold to various small factories in Norwich and vicinity, which formerly used steam and are now using compressed air in its place. I have nothing to do with the financial part of the business, and I do not know what the prices charged are, but these concerns at least have preferred to use air at the price at which it is sold rather than steam which they had been using.

MR. ATKINSON. It was a question in my mind as to whether at the price at which it is sold it pays the promoters.

MR. SHEDD. That I am unable to say.

MR. T. H. MCKENZIE. Are the pipes laid as water pipes are, below the frost?

MR. SHEDD. No; most of them are about four feet deep, but really there is no occasion to lay them below frost, except that it is desirable to have them so low that they will not be thrown by the frost.

MR. MCKENZIE. Why does the air blow-off blow both water and air?

MR. SHEDD. Because the inlet to the blow-off pipe is just at

the level of the air and water, and as the air begins to pass out it carries water with it, so that water and air are discharged.

A question has been asked me as to how the flashboards have worked in practice. The only trouble they have had from the flashboards has been that when they are open leaves flowing in the stream sometimes catch in the seats and flashboards do not entirely seat themselves afterwards, so that there is a little leakage for a time until the leaves are cleared from under the seat.

Mr. Frank L. Fuller. I should like to ask Mr. Shedd in regard to utilizing the different amount of flow at different seasons of the year. I think all the slides which were put upon the screen showed water running to waste.

Mr. Shedd. Yes; the plant is adapted to 1 500 horse-power, and the stream is usually capable of developing considerably in excess of that amount of power. Water, of course, is running to waste over the dam when there is only 1 500 horse-power or less going through the compressor. When the compressor is taking a less quantity, adjustment is made in the headpiece.

Mr. Fuller. I presume it is quite a variable stream.

Mr. Shedd. Yes; but it is pretty well reservoired. As near as I remember, there are forty-three different storage reservoirs on that stream. It rises in Worcester County in Massachusetts, and there are a great many mills on the stream; it has been very well developed for manufacturing purposes.

Mr. Fuller. Could not another compressor be used when there was plenty of water?

Mr. Shedd. Yes; there is an opportunity to place another alongside of this one. Everything has been so arranged that no disturbance would occur if another compressor of equal capacity were set alongside of this.

Mr. McKenzie. Is there any patent on the apparatus for the flashboards?

Mr. Shedd. Yes, there is.

Mr. McKenzie. Who owns it?

Mr. Shedd. I guess it is pretty nearly free.

Mr. McKenzie. What do you mean by its being pretty nearly free?

Mr. Shedd. Well, there wouldn't be much objection to anybody using it for these purposes.

Mr. Albert F. Sickman. I would like to inquire if you know what the efficiency of this compressor is?

Mr. Shedd. The efficiency has not been measured at this place particularly, but I took part in several experiments as to the efficiency of the plant of Magog, and that ranged from about sixty-two per cent. to a little over seventy per cent. The highest efficiency we obtained was a little over seventy per cent.

Mr. Sickman. Under what conditions would that be obtained? When you are using a great quantity or a small quantity?

Mr. Shedd. It is when using the quantity to which the compressor is adapted. I believe the local engineer has said he thought he could obtain somewhere near eighty per cent., but we have never, to my knowledge, accurately measured the efficiency at this point. The velocity of the water when it is entraining the air seems to be about eight feet per second when it is doing its best work, and under those conditions the efficiency, as I say, in the experiments in which I took part, was a little over seventy per cent.

Mr. McKenzie. What is the method of introducing the air into the water as it passes down?

Mr. Shedd. That has been done in various ways. At Magog it is done by a series of three-quarter inch pipes surrounding a circle, the upper ends above the level of the water and the lower ends at the point of the greatest velocity of the water as it flows into the down-flow pipe. The water passing by the end of the pipe tends to create a vacuum there and the air is drawn in and goes down in bubbles with the water. At Norwich the headpiece is a sort of gridiron with each bar hollow, open on the lower side and supplied with air at the ends, and the water passing down between these gridiron-like bars, the air passes horizontally through the bars into the water as it passes by. There is a plate nearly across the pipe, you might almost call it a pipe, a gridiron bar with a quarter-inch aperture on each side. The headpiece is under three or four feet of water all the time and the pipes to these gridiron bars rise above any possible level of the water in

the headpiece. They are 12-inch pipes with a 36-inch center pipe.

Mr. Fuller. I should like to ask Mr. Shedd with regard to the excavating of the well, whether that was expensive? I suppose there was a good deal of water which had accumulated which had to be constantly pumped.

Mr. Shedd. Very little indeed; it was very favorably situated in that respect. Down perhaps one hundred feet there was one seam which developed a pretty good flow of water, but otherwise the ledge was tight. That inflow was taken care of by an excavation in the side of the shaft and a dam between that and the shaft itself, making a well, out of which the water was pumped. We then had no more water to amount to anything until we were at the bottom of the shaft.

Mr. Fuller. How much did that excavation cost per cubic yard?

Mr. Shedd. I shall have to tell you from memory, but I think it was $3.50 a cubic yard.

Mr. McKenzie. Are there any patents on the general process of compressing the air?

Mr. Shedd. Yes. That was patented by a Canadian by the name of Taylor, in England and in this country.

Mr. McKenzie. Is there a royalty paid?

Mr. Shedd. That I don't know. I don't know what their business arrangement is, but I think the Norwich people are licensed by Mr. Taylor.

Mr. Sickman. What is the temperature of the exhaust at the engine?

Mr. Shedd. That varies. It is very low in cases. It has been low enough to freeze. We had no difficulty in Magog, but here there has been slight amount of moisture, and the temperature due to expansion is low enough to freeze that moisture unless the air is reheated. But when the air is reheated, which would, of course, be done in all cases if you are seeking economy, then there is no trouble of that sort. There have been a good many experiments made on the temperatures both of the air admitted and the air discharged, but I don't remember the figures. Our experiments showed that from about a third to a half as much moisture

was in the air delivered by the compressor as was in the atmospheric air from which it was drawn; that is, the air has been made dry by being enclosed in water.

Mr. T. W. Mann. In 1876, I think it was, I was in Rochester and they had a system of two tubes which were air tight and they let the water in at the bottom and compressed the air in one tube while the water was going out of the other tube, keeping a balance of pressure. I wonder whether that would not be a pretty good way to keep the moisture out.

Mr. Shedd. I don't know, myself, about the process the gentleman speaks of, but I should think it might be very much in theory like a process designed by Mr. Joseph P. Frizell, twenty years or more ago, for compressing air. He had a shaft above a dam down which water went carrying air with it and then he had a horizontal tunnel and a shaft below the dam so that there was a difference of level below and above the dam, and at an intermediate point he had a chamber in which the air was collected. I should think that would be similar to having two pipes. There have been a great many ways of entraining air and compressing it by water, and I think Mr. Frizell's was perhaps the first really practicable scheme. But that never has been put into commercial use, so far as I know, because it was an expensive process as he designed it.

Mr. Atkinson. I happened to be in Liverpool some twenty years ago and went to the great docks, and I found that all the power used there was compressed air. Of course, it would be very dangerous to have fire among the merchandise there. I am not mechanic enough to understand the details of it, but if any of you visit Liverpool I think you will find that the use of air pressure throughout the docks is very extensive. I once gave a hint to a mill man which may be worth the telling here. You all know that the fiber of cotton is exceedingly susceptible to the changes of temperature and humidity. Now, the air which goes down through the wheel pit gets washed and cooled. In the case of the gentleman to whom I refer the basement of his mill was on a level with the tail race, and in hot weather it was very damp and very objectionable. I suggested to him to put an air drum over the water in the wheel pit and to carry the cool, dry air through a pipe into

his picker room and from his picker room into the spinning room, and thus overcome the humidity. He adopted the suggestion and it worked very successfully. That same thing can be done in many places. There is an enormous quantity of air which goes down through the wheels, even without any artificial method of carrying it. I have been told that at a summer resort in Austria a mountain stream has been used to compress air, and one of the show features is to let the cool air out in midsummer and produce an artificial snowstorm. There is a head of about eight hundred feet which gives an enormous pressure.

Our old friend Sam Webber had an entirely new device for compression which he has described to me, and it made such an impression on me as it would naturally make on a "duffer." It was entirely different from Mr. Frizell's, and quite different from the one which was been described to-day. Then, I remember some twenty years ago the Plymouth Cordage Company desired to install an engine for hauling heavy stuff through their yard, and we objected to it. There was then devised an air locomotive and we sent the designs to the Boston Locomotive Works who built it without giving any guaranty that it would be efficient, but that little air engine is operating to-day, carrying around the heavy stock in the yard. When I returned from Liverpool I reported to the Cotton Manufacturers' Association that the English were a generation ahead of us in this country, but we appear to be catching up with them now in the use of air pressure.

THE DIRECT PUMPING METHOD OF WATER SUPPLY IN USE AT TAUNTON, MASS.

BY GEORGE A. KING, SUPERINTENDENT.

[*Read September 15, 1904.*]

When a member of the first board of water commissioners of Taunton, Mass., was seeking some one to take charge of their pumping plant, he expressed the feeling of that time toward the direct pumping system in this way, " We want a man who will make a success of a system which is condemned by every engineer." That was twenty-eight years ago, yet to-day I suppose there is much the same feeling in this part of the country, although the same system is being introduced in large cities under the name " high-pressure system " for fire protection. A plant operated by gas engines and carrying a pressure of three hundred pounds at the pumps has been installed at Philadelphia. New York and Brooklyn have both had the system recommended for them by competent engineers. Bids have recently been received for installing a plant in Brooklyn. Such a plant has been considered for Kansas City, and one has recently been installed at Charleston, S. C.

Thirty years ago the question of a water supply for the city of Taunton, Mass., was under consideration. Taunton was then a city of 21 000 people, but in area the largest city in New England. The population of the section to be supplied with water was estimated at 15 000. The area to be supplied varied in elevation from 5 to 70 feet above mean high water. The highest ground within several miles of the center, where a reservoir might be built, lay three miles to the north, and had an elevation of 200 feet above mean high water.

The feasible sources of supply were the Lakeville ponds, eleven miles to the southeast, and their outlet, the Taunton River, which flowed into the central part of the city from the east. The latter was selected, and a spot two miles east of the center

of the city was chosen as the most available place for taking the supply from the river.

Thirty per cent. of the voters were sure to oppose an expenditure from which they expected to receive no direct benefit. Many of those who could expect to be benefited were so conservative that they would vote against almost any new scheme involving an expenditure. The problem, therefore, was to draw an act to be acceptable to a majority of the voters. The question of the maximum expenditure was a vital one. It was decided to set this at two hundred thousand dollars. Political rather than engineering conditions determined the amount of the appropriation.

The estimates afterward made were as follows:

Reservoir Plan	$479 779.39
Standpipe Plan *	300 850.46
Direct Pumping Plan . . .	249 730.00

Thus it may readily be seen that the direct pumping system was the only one available, or, as stated by the commissioners in their first report, "With our limited appropriation, we could secure water works of greater value to our community by this system than by any other." The plant, with twenty-four miles of distribution mains, was installed for $254 000.

The first pumping plant consisted of a Holly compound engine with four double-acting pumps, constructed so as to be easily detached, so that one or more pumps might be used as desired. The capacity of this engine was 3 000 000 gallons per day. There was a reserve set of two rotary pumps with a capacity of 3 000 000 gallons per day, run by a horizontal high-pressure engine. This made our total pumping capacity at first 6 000 000 gallons per day. The boiler plant consisted of three 60-inch boilers, sixteen feet long.

The plant was started the first of December, 1876, and pumped on an average 360 000 gallons per day.

The daily consumption had increased to 1 000 000 gallons in

* The standpipe location on which the estimate was based would have been entirely unsatisfactory and would have necessitated the use of fire engines at most of our fires.

1891, when a 72-inch boiler and a 4 000 000 gallon Gaskill pumping engine were added.

In 1899 an entirely new boiler plant of four 72-inch boilers, from Edward Kendall & Sons, was installed. These were followed, in 1901, by the addition of a second Gaskill engine with a capacity of 8 000 000 gallons per day. These increases in pumping capacity were not necessitated by the increased consumption, but seemed desirable that we might be prepared for an emergency, such as a disastrous fire occurring during a time of large domestic consumption, when one of the pumps might be undergoing repairs.

Our plant to-day consists of four 72-inch boilers, operated in pairs alternately, using each pair thirty days. The fire under the idle pair is ready for lighting at any moment, although the boilers are not kept filled, as there is less corrosion by keeping them dry. We have a 12-inch steam pipe running from the boilers through the engine room. By this, steam may be taken from either or all of the boilers and delivered to either or all of the engines. We also have an 8-inch auxiliary steam pipe, entirely independent of the 12-inch, which takes steam at will from either boiler to either engine. The pumping plant consists of the Holly quadruplex engine of 3 000 000 gallons capacity, installed in 1876 and still in serviceable condition; the Gaskill cross-compound pumping engine of 4 000 000 gallons capacity, installed in 1891 and usually running from 6 P.M. to 6 A.M. each night; and the Gaskill cross-compound pumping engine of 8 000 000 gallons capacity, installed in 1901, running from 6 A.M. to 6 P.M. each day. We run these Gaskill engines alternately twelve hours each, that we may have a reserve engine always warm and ready for service. Two or more of the engines can be used at once when needed in case of fire or extraordinary consumption. Each engine is connected directly with the supply, and discharges independently into the distributing mains.

There are two 20-inch mains leading by different routes from the station to the center of the city, a distance of nearly two miles. There are now eighty miles of distributing mains, varying in size from 4- to 20-inch. The larger part of the water is carried over a mile from the station in the two 20-inch mains.

There are some branches nearer the station, and at a distance of a mile the branches run in such divergent directions that water is supplied from the station as a center to nearly three fourths of a circle. The most distant point to which water is carried is about five miles from the station. In the opposite direction it is carried about three miles. In lines at right angles to this longest diameter it is carried six miles. In topography this area varies in elevation from 5 to 90 feet above mean high water.

The pumping plant is operated by three shifts of two men each. The steam pressure carried at the boilers is 100 pounds; the water pressure at the gage is, for domestic use, 55 pounds. (The gage is 21 feet above mean high water.) When there is an alarm of fire, the pressure is raised to 100 pounds on the gage, and if the fire is at an elevation where there might be need of increased force, the pressure is raised to 105 or 110 pounds.

The time taken to raise the pressure from domestic to fire is not over three minutes. No fire steamers are used at fires in the district covered by our mains. The pressure needed is always available at the hydrant on the arrival of the hose wagon, saving at least two or three minutes' delay in setting and coupling engine to hydrant and hose to engine when the delay would be most disastrous. The value of time in the early stages of a fire is being more and more appreciated.

In our experience the direct pumping system has worked admirably. It is now nearly twenty-eight years since the pumps were started and they have never failed us. The machinery has been stopped twice. For several hours one night, when the last engine was installed, the pumps were shut down to allow a connection to be made with the steam pipe, and once since for a still shorter time, to repair a valve on the steam pipe. As now equipped, we would not shut down for either cause. There have been breaks in the mains which, until shut out or repaired, have caused the pressure to be greatly reduced, and when we had but one main leading to the center, a break in this entirely cut off the supply from the city.

If "the efficiency of a water works is measured by its ability to control a bad fire before it becomes a sweeping conflagration," as Mr. J. R. Freeman has said, then the direct pumping system,

as used in Taunton, has proved its efficiency in its twenty-eight years of service. It has never failed to be ready, and any deficiency has been clearly shown to be due to small mains and not to the pumping system. My predecessor as superintendent, Mr. George F. Chace, in a paper before this Association in 1891,* gave in detail the work done at numerous fires, and the record has been fully maintained up to this time. On the 16th of last month (August), at 1.27 A.M., in a stable and in a near-by laundry, was discovered a fire under good headway, so much so that nothing was rescued from the stable, and but little from the laundry. These buildings were surrounded by others but a few feet away. The fire was confined to the two buildings, controlled by eighteen good streams with first-class pressure. We pumped about $1\frac{1}{3}$ million gallons between midnight and six o'clock the next morning; this was pumped part of the time at the rate of 8 000 000 gallons per day.

The total expense at our pumping station last year was $9 363.78. The chief engineer of our fire department tells me that if he had to use steamers to obtain the necessary fire pressure, as he undoubtedly would under any other system, the extra annual cost of his department would be about $25 000.

Mr. George A. Ellis, in a paper before this Association, said, "If the pipe system is well designed, able to convey the volume of water required without undue loss from friction, and the pipe itself able to withstand the strains and shocks arising from direct pressure, then direct pressure is desirable for fire protection." We have experienced no shocks and apparently no strains, except what would be produced under any system with equal pressure.

There is some indication that others are coming to be of the same opinion as Mr. J. N. Tubbs, of Rochester, N. Y., was thirteen years ago, when he said, "As a device for the suppression of fires, I believe it to be unequaled, and I am inclined to the opinion that the general adoption of this or some similar system in all large cities and manufacturing towns where valuable buildings, merchandise and industries are concentrated, will be found the most effective and cheap means for fire protection."

*JOURNAL, N. E. W. W. Assn., Vol. 6, p. 67.

DISCUSSION.

Mr. Frank E. Merrill. I should like to ask Mr. King what effect the increase from domestic to fire pressure has upon the plumbing in the houses.

Mr. King. The tanks of the water-closets have frequently caused trouble on account of leaking because of the increased pressure. When the pressure goes up to fire pressure, the valves which have been set to work on 55 pounds will frequently leak.

Mr. Merrill. Is the city metered?

Mr. King. About forty per cent.

Mr. Merrill. And on account of the waste from the ball cocks occasioned by the increase of pressure, do you not sometimes have complaints from the consumers because of the extra amount of water which passes through?

Mr. King. We do have plenty of them.

HASKELL'S BROOK RESERVOIR AND DAM, GLOUCESTER, MASS.

BY H. W. SPOONER, CIVIL ENGINEER, GLOUCESTER, MASS.

[*Read September 15, 1904.*]

The city of Gloucester has a system of water works which has an interesting history. The writer will not attempt, however, to give details at this time of the ways and means which were utilized to supply this old and beautiful Massachusetts locality with water for domestic and other purposes, but will endeavor to describe only the construction of the new impounding reservoir, the preparation of the basin, and the building of the dam.

The original plant was constructed by George H. Norman and owned by the Gloucester Water Supply Company. This company contracted with the city to furnish fire protection, etc., under contracts which were to expire in 1896, previous to which time, however, the city acquired possession of the works, and it was necessary to immediately commence improvements and additions.

By referring to a schedule prepared by the writer, — Plate I, showing the number of gallons of water pumped since the first record was kept, — and remembering the fact that the estimated average daily yield of both sources originally acquired by the city is about 900 000 gallons, one may readily perceive that even previous to the time that the city obtained possession of the works, a further or added source of supply was necessary in case of exceeding dry weather. On account of the slight depth and the nature of the bottom of the Wallace Brook Reservoir, the water from that source is not fit for use during the warm season, and the only supply at the disposal of the city which could be depended upon for use throughout the year was the Dikes Meadow Reservoir.

From the second annual report of the board, the following quotation is taken: " The supply of water has been sufficient

for our needs this year, but we recognize the fact . . . that we shall need an increased supply."

From the report of 1898 it may be seen that although extensive changes were made at the pumping station, no beginning was made upon an additional supply.

In the report for the following year, a report of Engineer Percy M. Blake may be found, in which he discusses an additional supply from either of two sources — one being the Chebacco Lakes, the other Haskell's Brook.

During the year 1900 the writer, at the request of the water board, made a survey of the Haskell's Brook watershed, commenced surveys for the definite location of an impounding reservoir in the valley through which the brook flows, and made a report of his findings.

In 1901 the city council voted an amount of money for additional water supply, and the water board decided to utilize Haskell's Brook by erecting a dam across the valley three thousand feet or more above the site of an ancient sawmill, impounding the waters of the brook and conducting them to the pumping station by a gravity conduit composed of 20-inch cast-iron pipe.

Early in July an engineer corps was organized, and under instructions from the board surveys were recommenced, and in September plans of all lands affected by the construction of the proposed reservoir were laid before the commissioners.

After considering the matter at length, the board decided to "take," by right of eminent domain, all properties within the lines laid down and necessary to the project, the required plans and papers were filed, and the work of clearing and preparing the basin for the storage of an additional supply of water for domestic and other uses was commenced under the personal direction of the writer on October 30, 1901. It was the intention of the board to do the work upon this basin by day labor, and the removal of timber, brush burning, etc., was done by citizens of Gloucester, the wage rate being two dollars per day of eight hours.

A location for the site of the basin was chosen in a portion of the valley upon the east side of which the earth was of gravel and ledge, having a very slight coating of loam; upon the west

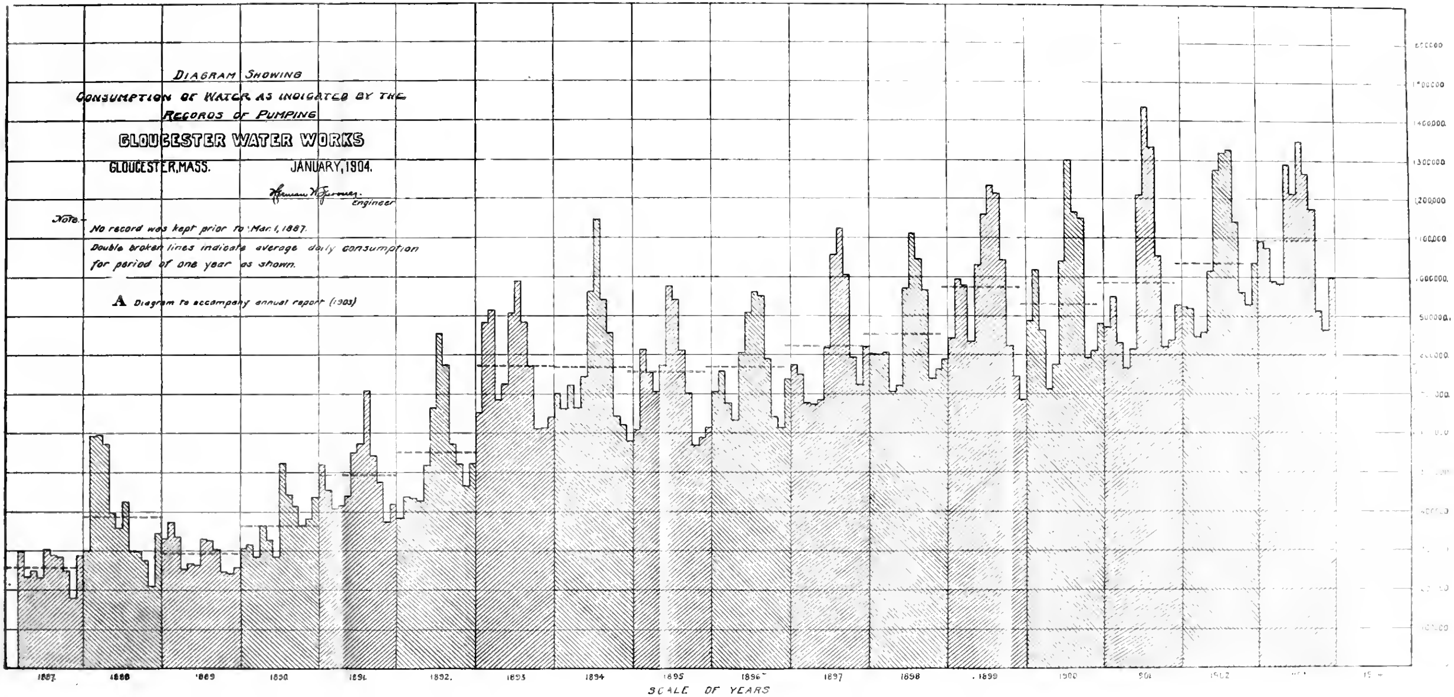


DIAGRAM SHOWING
CONSUMPTION OF WATER AS INDICATED BY THE
RECORDS OF PUMPING
GLOUCESTER WATER WORKS
GLOUCESTER, MASS.
JANUARY, 1904.
Engineer
Note.-
No record was kept prior to Mar. 1, 1887.
Double broken lines indicate average daily consumption
for period of one year as shown.
A Diagram to accompany annual report (1903)
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
1887
1888
1889
1890
1891
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SCALE OF YEARS

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PLATE II.

HASKELL POND, LOOKING SOUTH FROM TOP OF "SUGAR LOAF," NEAR ORIGINAL DAM. — Sept. 9, 1901.

side, disintegrated ledges and bowlders and a very little gravel were found. The hills rose abruptly from the edges of the ancient pond (Plate II), the waters of which (having a maximum depth of four feet) were formerly impounded and used by the owners of a sawmill which was situated some distance below on the line of the brook.

After the pond, which had an area of about twenty-six acres, was drained and the obstructions removed from the brook bed, it was found that the silt had accumulated for centuries in the bottom of the valley, leaving the bottom of the pond practically level, with a maximum known depth of silt, vegetable matter, etc., of sixteen feet. As the watershed above this site is entirely free from dwellings of any description and practically free from large, swampy areas, it was decided that by careful work upon the basin proper, water of excellent quality could be obtained from this source.

The removal of wood was practically completed prior to the opening of the spring of 1902, at which time the writer began detailed operations upon the proposed dam site, and the preparation of the bottom of the basin was placed in charge of Superintendent John W. Moran.

As it was found that, on account of the excessive depth of silt, it would be impracticable to remove it from the basin, borrow pits were opened in the sides, and the work of covering the entire reservoir bottom, an area of about twenty-six acres, with clean earth was commenced in 1902, citizens of the city only being employed at the rate above-mentioned to do this portion of the work, which was completed in September, 1902, the depth of cover averaging about one foot.

While the above work was being carried forward, the sides of the reservoir were grubbed, the stumps removed, and a small roadway constructed across a shallow arm of the pond on the east side. This roadway was one of the original ways to the wooded properties beyond the pond, and, as constructed, the waters collected in this shallow portion of the reservoir are held, the water passing from the surface of this section of the basin to the main reservoir in freshet season through a culvert near the surface of the roadway.

The plans for the construction of the main dam were completed, a contract and specifications prepared, and bids called for by the writer under direction of the water board. On the opening of the bids, the contract was awarded to Coleman Brothers of Everett, Mass.

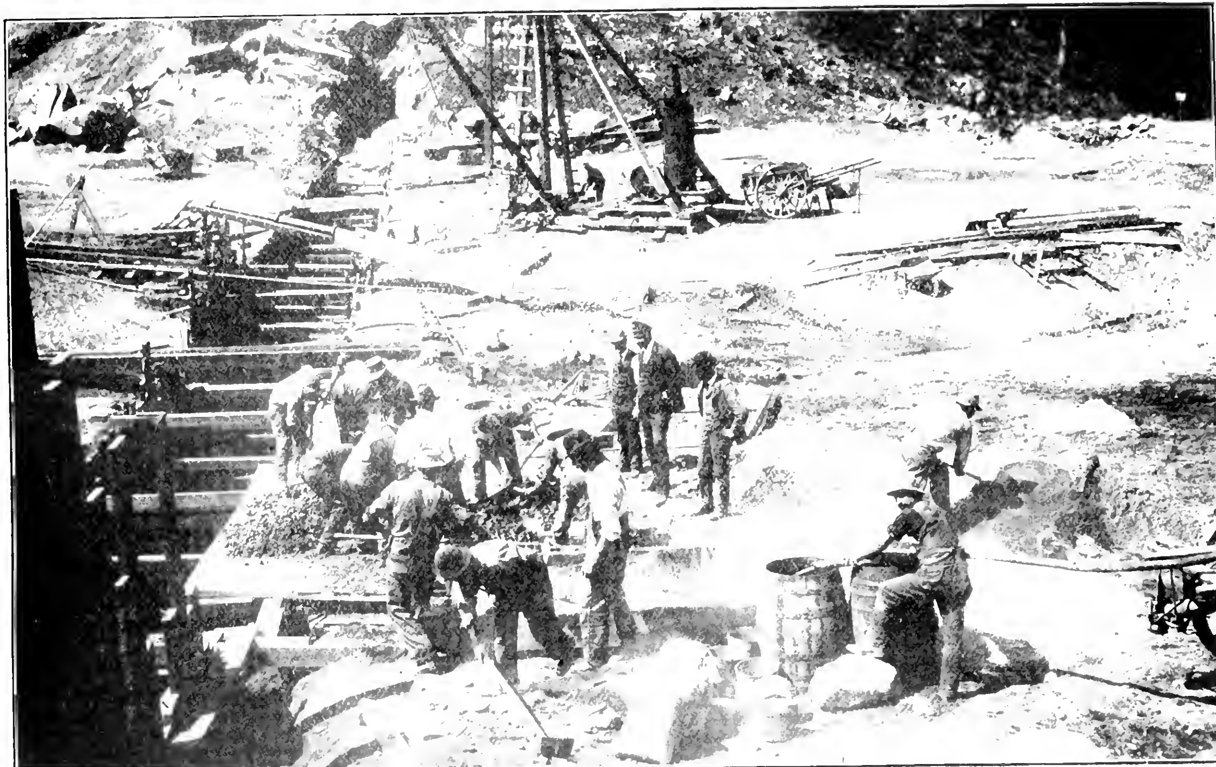
This work was commenced on July 23, 1902, and completed on August 8, 1903, the reservoir containing at the time of the completion of the structure a maximum depth of water of 20.17 feet.

The work was commenced by stripping the site of the dam of all loose bowlders and muck, and excavations were begun for the core wall, gate-chamber, and gate-house foundation. These excavations were extended to ledge or a suitable bed of hard pan upon which the concrete work was laid. The trench for the core wall foundation (Plate III) was opened entirely across the valley, and the concrete wall was constructed in layers of from three to four feet in depth, the top of each stratum being grooved by the use of a piece of timber eight inches square embedded in the concrete when placed. After the concrete was set, these timbers were removed, leaving an indentation which was filled with cement just prior to laying the succeeding course. The entire work was carried up in layers which reached across the valley (Plate IV), the earth forming the embankments being spread about one foot in depth, then rolled and puddled. The slope toward the pond was paved. The gates in the gate-chamber were set in place as the grade of each was reached. The work was carried up in this way (the valley sealed for its entire width) so that as much water as possible might be stored in the basin at the earliest possible date.

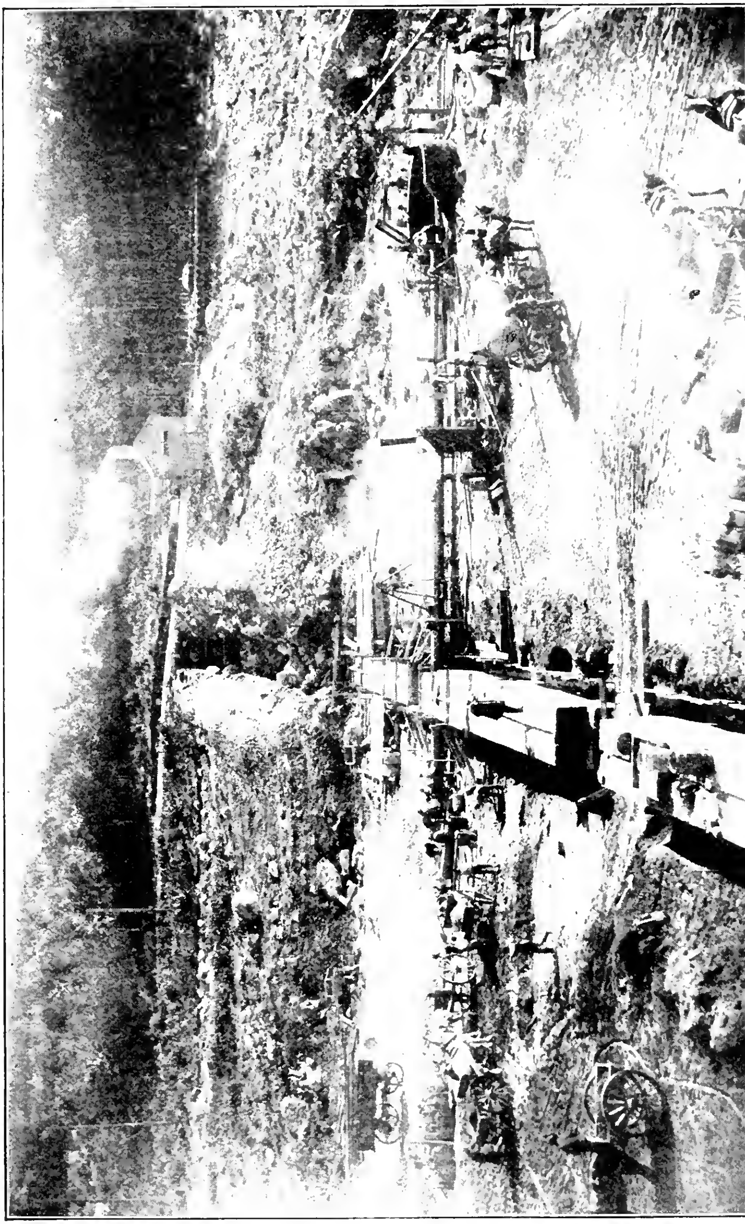
Large quantities of the material used in forming the embankments were taken from borrow pits situated inside the basin, a pit being opened on the outside when, on account of the rising of the waters, the inside pit could no longer be utilized.

The stone used in the concrete was crushed upon the work; all bowlders removed from the site of the dam were hauled out upon the pond bottom, broken up and delivered to the crusher, and, later, stone from the pits was utilized. As no suitable sand was found near the site of the work, the contractors were obliged

PLATE III.



VIEW LOOKING WEST, SHOWING CORE WALL TRENCH AND FIRST CONCRETE WORK. Sept. 11, 1902.



LOOKING EAST ALONG DAM, SHOWING CORE WALL, 20-INCH PIPE, AND GATE CHAMBER COMMENCED. — Oct. 10, 1902.

to haul all that was used from a pit some three quarters of a mile distant.

The dam, built in strict accordance with the original design, is what is known as an earthen core-wall structure, a core of concrete being erected in the center of an earthen bank throughout its length, the top being two and one-half feet above the normal flow line of the reservoir.

Within the basin and rising through the embankment about half way up the inner slope, a circular gate-chamber, fifteen feet in interior diameter, built of concrete and lined with brick, was constructed (see Plates V and VI). Wing walls project from this chamber to the outer lines of the embankment, forming an open passage five feet in width at the bottom of the chamber; in the bottom of this passage is the blow-off or scouring pipe and the lower end of the twenty-inch automatic overflow pipe.

The intakes consist of cast-iron pipes set in the concrete walls, six feet apart vertically, and upon different sides of the chamber. On the inside of the tower and bolted to the flanged ends of the intake pipes are the gates, which are of the adjustable pattern of sluice-gate made by the Coffin Valve Company. These gates are operated in the brick superstructure which surmounts the chamber by wheel stands connected with the gates by two-inch steel rods. Within the chamber, brick walls project inward from the lining, into which iron screenways are built; screens of copper wire, with hard-pine interlocking frames which were furnished by the Coffin Valve Company, are operated in the screenways, and may be removed and cleaned at will.

A gate-house of brick, built outside of and below the dam, contains the gate valves that are located upon the delivery main, scouring pipe, and by-pass. This last valve is used when the gate-chamber is cleared or water withdrawn for repairs, allowing the delivery main to remain full below the gate-house, the by-pass making a cross connection between the delivery main and scouring pipe.

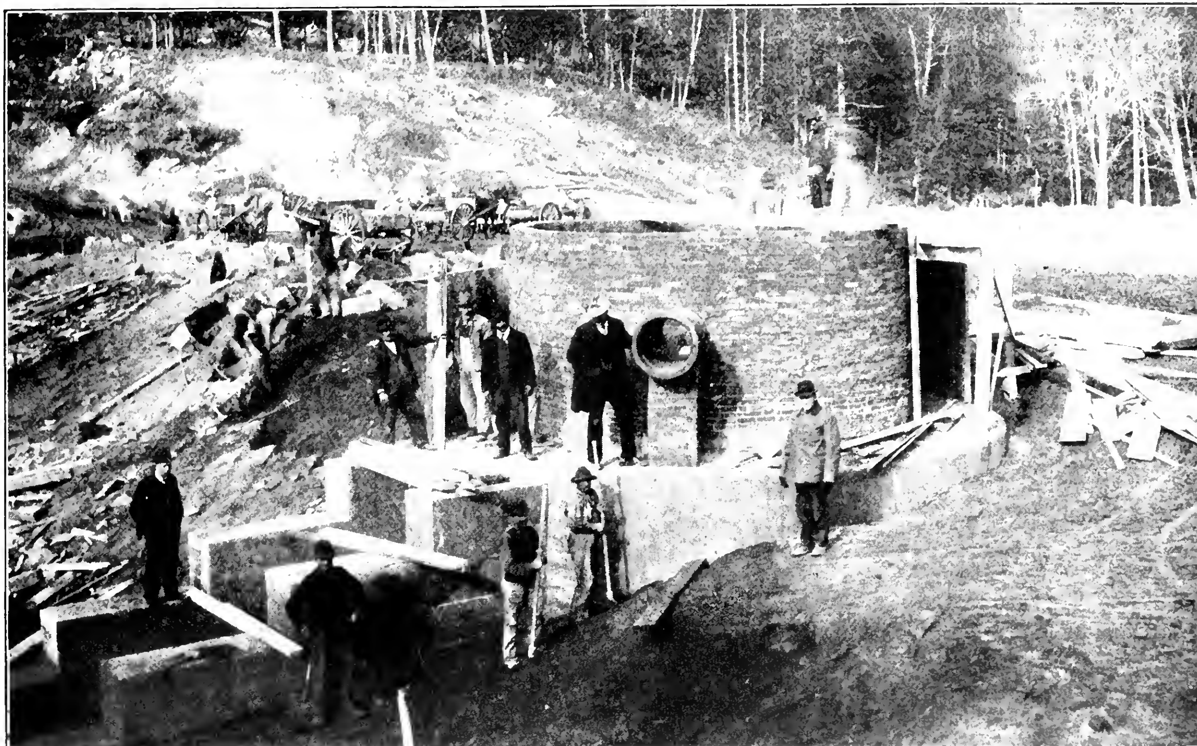
The automatic overflow before mentioned was introduced into the work at the suggestion of Mr. William Wheeler, civil engineer, of Boston, who served as consulting engineer upon this work. It consists of a line of 20-inch Akron pipe laid from the bottom

of the passage before mentioned, under the paved inner slope of the dam to the wasteway, and there discharging the waters from the bottom of the basin when the water reaches the normal flow line. It will be observed, therefore, that the normal waste of water from this reservoir is from the bottom, the water of poorest quality being wasted with the aid of this device, while the better quality of water near the top of the reservoir is taken for use through the intake which is nearest the surface.

The wasteway is fifteen feet in width, the waste waters being conducted to the original brook bed below the dam by a paved way, the paving of which is laid in cement.

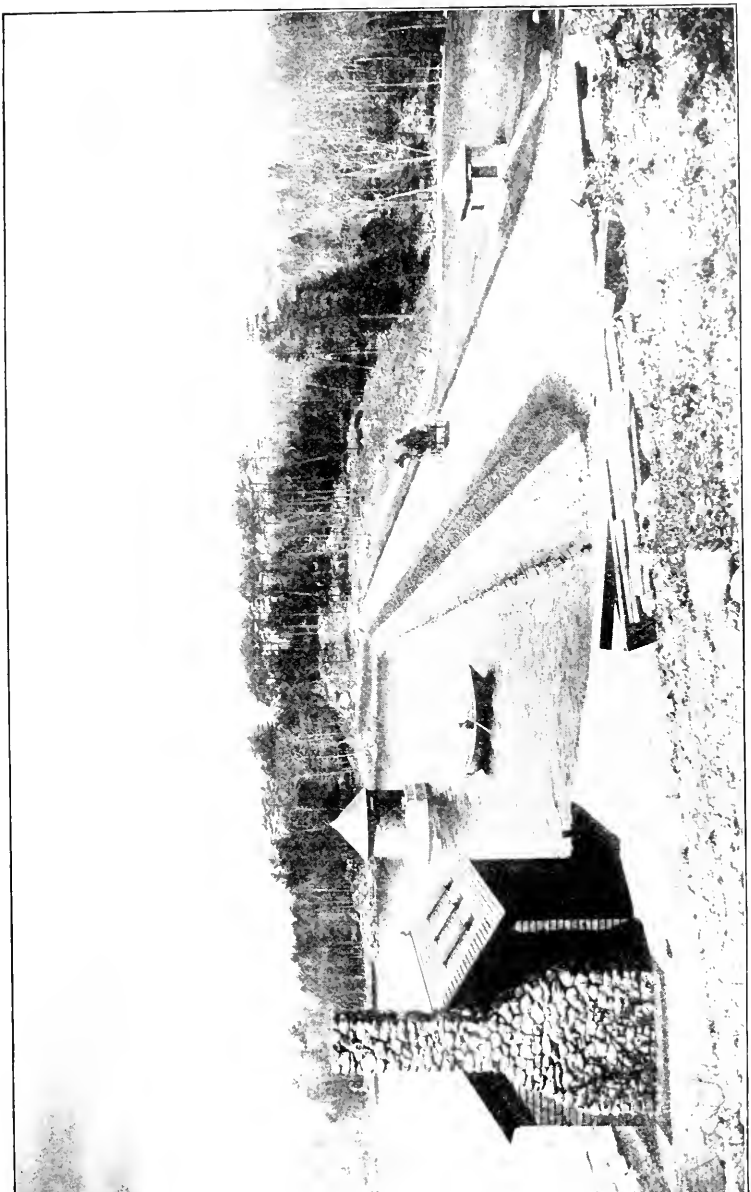
The inner slope (2 and $2\frac{1}{2}$ to 1) of the structure is paved with granite blocks, while the outer slope (2 and $2\frac{1}{2}$ to 1) is grassed. A roadway extends along the entire top of the structure (Plate VI), connecting the original wood roads on either side of the valley.

The reservoir is about one mile in length and covers about 57 acres, the watershed containing about 325 acres. The basin contains at the normal flow line about 427 000 000 gallons, having a maximum depth of 37 feet, the average depth being 23.06 feet. The above capacity may be increased (in fact, the water level is at present above the normal flow line) by the use of flashboards at the wasteway, the possible increase being about 48 500 000 gallons.



GATE CHAMBER UNDER CONSTRUCTION, SHOWING BLOW-OFF GALLERY, CONCRETE WORK, BRICK LINING, AND INLET PIPE AT ELEV. 87. – NOV. 1, 1902.

PLATE VI.



COMPLETED DAM, LOOKING WEST. — Aug. 19, 1903.

DESCRIPTION OF CONCRETE-STEEL WATER TOWER AND STANDPIPE AT FORT REVERE, HULL, MASS.

BY LEONARD S. DOTEN, CIVIL ENGINEER, QUARTERMASTER'S DEPARTMENT, UNITED STATES ARMY, BOSTON, MASS.

[*Read December 14, 1904.*]

Whether one enters Boston Harbor from the open sea or sails down the channel towards Boston Light, the most conspicuous landmark which attracts the eye is the tower-like structure standing on the summit of Telegraph Hill in Hull. This is the concrete water tower constructed by the government in connection with the water-supply system for the military post known as Fort Revere, and situated at an elevation of one hundred and thirty feet above the sea level. Its advantage of position not only affords good water pressure in the military post water mains, but also makes it a landmark which is often used by navigators at sea for determining their position as they approach the coast. Additional interest is attached to its location from the fact that it is built on one of the bastions of a Revolutionary fort, commonly known as " the old French fort." It is a unique engineering structure, having been erected at a time when reinforced concrete construction in this country was in its early stage of development, and has the distinction of being the first water tower in this country constructed of this material.

Plans and specifications had been prepared in the Boston office of the quartermaster's department, United States Army, in the spring of 1902, for a tower to enclose the steel standpipe which the department proposed to erect in connection with a water works system for the fort. Its purpose, on account of its proximity to the fine residences of the town and its conspicuous location, was twofold, — to protect the standpipe against possible destruction by the formation of ice cores during the winter, and to add an interesting feature to the landscape, rather than a

disfigurement. The design, however, was later considerably modified to lessen the cost of construction.

In May, 1902, the department advertised for proposals for the construction of the tower. According to the instructions given to bidders, contractors were allowed to submit proposals for either a brick masonry tower or a stone masonry tower of the same general design. There was also a further provision allowing a contractor to submit a proposal for the construction of a tower and standpipe from his own plans and specifications, the standpipe to be of the same dimensions as those given in the plans prepared in the quartermaster's department. The proposal finally accepted was that of Mr. R. Baffrey of New York City, which was based on the construction of a concrete-steel tower and standpipe designed in accordance with the Hennebique system of armored concrete.

The authorization for the building of a structure so radically at variance with the best engineering practice at that time, by a department of the government known to be conservative in its methods, could only be accounted for by the fact that it desired by means of experiment to find a material more durable and economical in maintenance than steel for standpipe construction. The annual cost of maintenance of steel standpipes and similar structures is an important factor to be considered by any corporation. This is especially true when they are located along the seacoast and in tropical climates. Therefore the conclusion was reached that if concrete standpipes could be constructed which would prove satisfactory structurally, the solution of the problem was found.

Work was begun on the tower in the latter part of June, 1902. The concrete work was completed that fall, but the tower was not fully completed and accepted until June, 1903. Water was turned on late in the fall of 1902, and the standpipe was filled for the purpose of testing it. So far as the concrete was concerned, the test was satisfactory, but it was necessary to draw off the water in order to repair some leaks which developed around the inlet pipe connection and around the iron manhole cover. The defects were easily remedied. During the remainder of the winter the pumping was so regulated as to keep the standpipe

Concrete-Steel Water Tower at Fort Revere.

about one third full, for above that height there was no protection from the frost, as the brick panels in the walls of the tower were not in place. Since the tower was completed and accepted, in June, 1903, it has been in constant use and has given perfect satisfaction. It has never leaked, nor has there been any indication of seepage through the walls.

The tower is octagonal in form, 33 feet in width at the base and 84 feet in height, measured from the grade line of the base to the apex of the steep pyramidal roof which surmounts the structure. It is constructed principally of reinforced concrete. The massive base, the eight columns supporting the superstructure above the standpipe, the floor and walls of the observatory, and the winding stairs extending from the entrance of the tower to the observatory, are all constructed of this material. The deeply recessed panels between the columns are formed of buff-colored pressed bricks. The roof structure, which is of wood, rises eighteen feet above the masonry of the tower and is covered with black slate. The character of the architectural design, assisted by the harmonious colors of the concrete and brick walls, makes the tower an attractive feature in the landscape. (See Plate I.)

The foundation of the tower is constructed of concrete composed of one part Portland cement, three parts sand, and five parts broken stone. As the soil on which the foundation was to rest was of a firm, unyielding nature, locally known as "hard-pan," it was not deemed necessary to place it lower than would be required to insure it against the action of frost. The depth of concrete below the finished grade is five feet. A portion of the foundation is taken up by a valve chamber, 5 feet by 9 feet in plan and 6 feet in height. The walls of this chamber extend two feet below the bottom of the other portion of the substructure, and they are reinforced with $\frac{3}{8}$-inch steel rods. This chamber contains the 6-inch inlet and outlet pipe, the 6-inch drain pipe, and the two gate-valves controlling these pipe lines. Fig. 1 shows an elevation and section of the tower and tank.

The concrete base of the tower is 4 feet thick at the grade line, and for a height of 4 feet the inner and outer surfaces are vertical. Above this point it batters on the outside to a thickness of 2 feet

at an elevation of 11 feet above grade. The concrete base is terminated at the top by a belt course 2 feet in thickness and

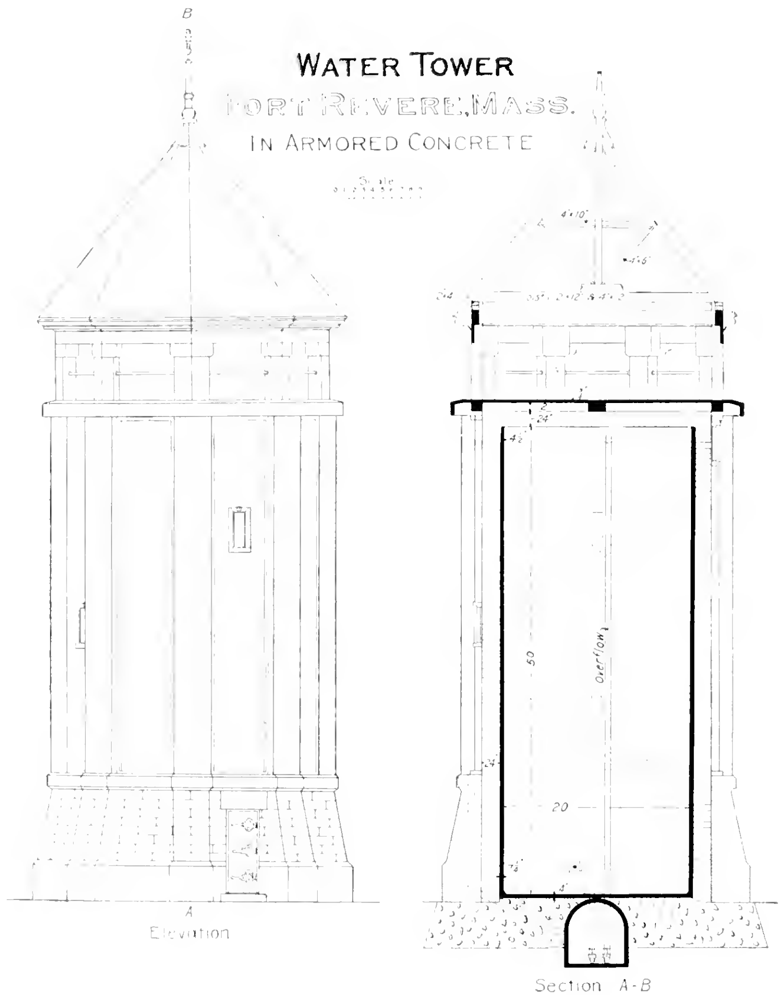


FIG. 1.

projecting 15 inches beyond the outer face of the base. The external face of the base is divided into rectangles by deep grooves,

which give it the appearance of regular coursed ashlar masonry. The concrete forming this portion of the tower is reinforced by $\frac{1}{4}$-inch steel rods and stirrups.

Resting on this base as a foundation are eight reinforced concrete columns 38 feet in height, which support the upper portion of the tower and roof. These columns are 3 feet 6 inches wide on the external face, and 3 feet on the internal face, and 2 feet thick. They are each reinforced by six 1-inch vertical rods extending the entire length of the columns.

The spaces between the columns are filled with 8-inch walls laid with buff-colored pressed face brick. Capping the columns and brickwork panels is a massive coping of reinforced concrete, which overhangs the columns on the exterior two feet, and forms the support for the concrete floor of the observatory.

Immediately above the main columns of the tower, and rising six feet above the floor of the observatory, are smaller columns which support the roof. The spaces between the columns are left open, with the exception of a $2\frac{1}{2}$-inch galvanized iron bar across each, about $2\frac{1}{2}$ feet above the floor.

The concrete floor of the observatory is $3\frac{1}{4}$ inches in thickness. It is reinforced by $\frac{1}{2}$-inch rods and supported by two 8×16-inch reinforced concrete girders, which are 8 feet apart. The floor was designed to carry 60 pounds per square foot.

The roof was strongly constructed of spruce timber and sheathed with dressed tongued and grooved boards. The slate used were the best quality of unfading black, and were secured to the sheathing with copper nails. The cornice, finial, and weather vane were formed of heavy galvanized iron.

The stairway, which almost completely encircles the standpipe, extending from its base nearly to the top, is also of concrete-steel construction. Small platforms anchored to the main columns of the tower at regular intervals form the supports for straight flights of stairs connecting them. The stairway does not come in contact with the standpipe at any point.

The most unique feature of the entire structure, and unprecedented in the nature of its construction in this country, is the concrete standpipe, some details of which are shown in Fig. 2. It is 20 feet in internal diameter and 50 feet in height, having,

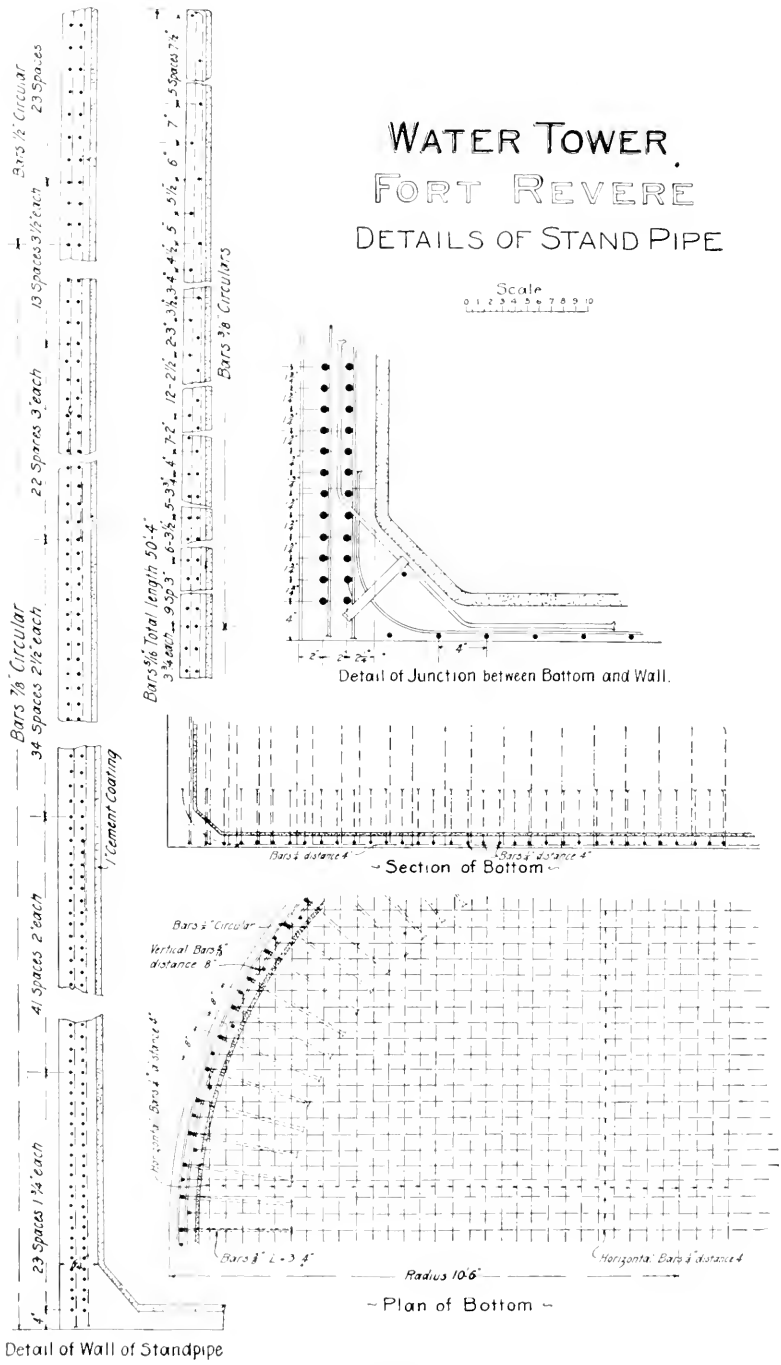

WATER TOWER
FORT REVERE
DETAILS OF STAND PIPE
Scale
Bars ½" Circular 23 Spaces
13 Spaces 3½" each
22 Spaces 3" each
Bars ⅞" Circular 34 Spaces 2½" each
41 Spaces 2" each
23 Spaces 1¾" each
1" Cement Coating
Bars ⅜" Circulars
Detail of Junction between Bottom and Wall.
Section of Bottom
Plan of Bottom
Radius 10'6"
Detail of Wall of Standpipe

Fig. 2.

therefore, a capacity of approximately 118 000 gallons. The walls of the standpipe are formed of a thin shell of concrete, $6\frac{1}{4}$ inches in thickness at the base and $3\frac{1}{4}$ inches at the top, in which is embedded a complex system of steel rods. The interior surfaces of the standpipe were later made smooth and impervious by applying to them three coats of Portland cement plaster, this waterproofing having a uniform thickness of one inch.

The inner form was first placed in position. It consisted of four horizontal rings of equal heights placed one above the other, each being divided into eight equal segments formed of plank ribs and vertical lagging. The whole inner form was rigidly braced and tied together inside. The outer form was so constructed that it served a double purpose, being also used for a scaffold in placing material. Uprights were placed radially in two circles about four feet apart on the inner one. These were firmly held in position by braces, the inner circle being properly adjusted with reference to the inner form to give the required thickness of concrete at all elevations. After the rods were placed in position, $\frac{1}{2}$-inch boards were bent horizontally until they formed a true circle in contact with the inner faces of the uprights. These were placed or driven into position a little in advance of the concrete filling.

Portland cement concrete, mixed in the proportion of one part cement, two parts sharp sand, and four parts coarse gravel, not over one inch in diameter, was deposited between the forms and worked around the rods in such a manner as to leave no voids. The reinforcement of the walls of the standpipe consists of horizontal rods in the form of rings, and vertical rods. In the lower portions of the standpipe the horizontal rods are $\frac{1}{2}$-inch in diameter, and when placed in position formed two concentric rings in each plane. At the base the vertical distance between the planes was $1\frac{3}{4}$ inches. This interval was gradually increased toward the top until the final intervals were $7\frac{1}{2}$ inches. The vertical rods were $\frac{5}{16}$ inch in diameter, and placed 8 inches on centers and wired to the horizontal rods at each point of contact. They were placed in such a manner that one half of the rods were in contact with the inner rings and the other rods with the outer rings.

In the bottom were embedded two systems of rods, placed at right angles to each other and wired together at all intersections. These rods were $\frac{1}{4}$ inch in diameter and placed 4 inches on centers. The angle between the bottom and sides was also reinforced with $\frac{3}{8}$-inch rods, 3 feet 4 inches in length and placed radially, these being about 8 inches on centers at sides.

The standpipe is provided with an outside overflow pipe extending from a point one foot from the top to a junction with the drain pipe in the valve chamber. It is a 6-inch wrought-iron pipe and is provided with an expansion joint.

The erection of this standpipe has been a successful experiment, and has demonstrated the adaptability of concrete-steel as a material for structures of this class, when it is properly handled. This form of construction, in its marvellously rapid development in this country, is a subject in which water-works engineers are becoming deeply interested. It possesses great possibilities in such structures as dams, reservoirs, filter beds, aqueducts, standpipes and water mains, but many failures must necessarily follow its use along these lines through faulty designs or the inexperience of those in charge of construction.

DISCUSSION.

Mr. Edward Atkinson. I should like to ask if the floor stresses and lateral stresses are carried entirely by the steel, or if any reliance is placed upon the concrete?

Mr. Doten. The floor stresses are carried by the concrete base. It is a very thick mass of concrete, and it is reinforced by small rods, not so much for strength, perhaps, as to prevent cracks at the surface from the contraction of the concrete. The walls are entirely dependent upon the steel reinforcement; no dependence at all is placed upon the concrete for tensile strength.

Mr. Atkinson. I find that the most conservative engineers are inclined to the belief that all the stresses, except of thick masses of concrete for vertical stress, should be carried wholly by the steel, and the concrete is merely a protective covering and to support the steel.

A Member. Will you state the cost?

Mr. Doten. The water tower and standpipe complete cost $11 980.

Mr. F. I. Winslow. Will you please state where the water supply is obtained for the standpipe?

Mr. Doten. It has been taken from a driven well on the Reservation, but that has not proved altogether satisfactory, and I believe the department is planning to take the water from the Hingham system.

Mr. Desmond FitzGerald. How much space is there between the inner shell and the outside?

Mr. Doten. About two feet. Of course the tank is circular in form, and the tower is octagonal; about two feet is the least space.

Mr. A. O. Doane. Has any trouble been experienced from freezing and ice pressures?

Mr. Doten. The tower, of course, is intended to protect the standpipe from the frost, but accidentally last winter the standpipe was left full of water during the coldest period, and was shut off from the system for a short time, — three or four days; and I understand from the commanding officer that about three inches of ice formed on top of the water. There has not been any heavy mass of ice.

Mr. Doane. I should think in case any heavy ice formed, as it does in steel standpipes very often in our New England climate, it would be very injurious to such a structure as this. There is a certain amount of elasticity in steel which such a structure as this lacks.

Mr. Doten. I do not think there is much more danger from ice in a concrete standpipe than there is in a steel one. You can very definitely determine how much steel is required in such a structure as this to resist certain pressures, and quite as well as you can in the case of a steel structure.

Mr. Horace G. Holden. How did the cost of this compare with an ordinary steel standpipe?

Mr. Doten. This one was somewhat cheaper. I could not say as to all sizes, for it depends somewhat on the conditions and size of the standpipe; but generally I should say that the type would be cheaper than steel.

Mr. Charles N. Taylor. Is it considered necessary to have this outside covering? Would it not be all right, if it were not for the appearance, to have the standpipe without the tower, the same as if it were of steel? Of course with a steel pipe you wouldn't ordinarily have any such outside covering as you have there.

Mr. Doten. I do not think it is necessary to have a tower enclosing the standpipe. The original idea was to have an ornament on the hill rather than a disfigurement. The contractor who constructed it did not think it was necessary to have any protecting tower, but it was merely a requirement imposed by the government.

Mr. Taylor. Wasn't the largest part of the expense in building the enclosing tower?

Mr. Doten. Yes, sir.

Mr. Taylor. In your opinion, what would the cost of the standpipe itself have been if you had left out the outside part of it? Should you say it would have been less than half?

Mr. Doten. Oh, yes, indeed; I should suppose, possibly, $4 000.

Mr. Taylor. And you think that that would have withstood the action of frost equally as well as steel if it had no protection?

Mr. Doten. Yes, if it had been designed with that in view. Of course we knew it was to be enclosed; perhaps it might have been more heavily reinforced if the standpipe had been designed to be exposed.

METER RATES.

[Topical Discussion, November 9, 1904.]

PRESIDENT BROOKS. The report of the Committee on Meter Rates is now in order.

MR. CALEB M. SAVILLE.* If I am the only member of the committee present, Mr. President, all that I can report is that your committee is working on the subject, and we hope before long to be able to present something for your consideration.

THE PRESIDENT. Has Mr. Merrill anything to say?

MR. FRANK E. MERRILL.† I will say, Mr. President, that my associate on the committee, Mr. Saville, has covered the ground thoroughly in his report. (Laughter.) I would suggest, however, that instead of the report of the committee, you ask for suggestions from members of the Association, and I am sure that anything in that line will be thankfully received by the committee.

THE PRESIDENT. Following the suggestion of Mr. Merrill, I would say that if there is any one present who has any idea to express in regard to what should be embodied in the report of the Committee on Meter Rates, we should be glad to hear from him.

MR. HUGH MCLEAN.‡ This matter of a standard metered price to all users of water is something that I have given considerable thought to, and I hoped that there would be some report made to-day that would give me some light on the subject.

My idea is that all metered water should be charged to all parties at the same price; that all consumers of water should be charged so much per thousand gallons, whether they use a million gallons or a thousand gallons. In our city of Holyoke, if the monthly consumption is 50 000 gallons or less, the rate per 1 000 gallons is 12 cents net; for a monthly consumption in excess

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* Division Engineer, Metropolitan Water Works, Boston, Mass.

† Water Commissioner, Somerville, Mass.

‡ Member Water Board, Holyoke, Mass.

of 50 000 gallons, and not exceeding 200 000 gallons, the rate is 8 cents net; and if the amount used per month is in excess of 200 000 gallons, the rate per 1 000 gallons is 4 cents net. Now, I contend that this is wrong. Other members of the Association may not agree with me, but following up the argument presented by Mr. Tighe in his paper at the Holyoke convention on assessing values of municipal ownership in water departments, it seems to me that the equalization of meter rates is a problem worthy of the attention of this organization.

I contend it is the duty of the municipality to sell water to all its citizens at the same price, and that the sooner a uniform charge per 1 000 gallons is adopted by a water department, the better and the more satisfactory it will be to all the citizens.

I might cite to you the fact that the present system encourages concentration of capital to the disadvantage of the individual. I might cite to you the fact that a large number of men may get together and call themselves a company, and by consuming a large amount of water, get it at the low rate. I can cite as a fact that this thing is being done in some cities in New England, and the only way to obviate it, and to make the cost of water the same to all, is to have a uniform rate of charge to every citizen. It may not be possible to have the same rate in all cities, but in every city there should be a uniform rate to all consumers. For instance, take the American Writing Paper Company in Holyoke, since the amalgamation of the paper interests called " the combine "; previous to that amalgamation the water for each mill was metered and each paid for its own water. Take the American Thread Company; previous to the amalgamation of all the thread interests, each mill paid for its own water. Now, by using a great quantity of water, they get it at the low rate of 4 cents per 1 000 gallons.

Now, what is to prevent similar amalgamations of interests in other cases? For instance, all the users of water for elevators in a city may get together and call themselves the American Elevator Company, and own all the elevators and have the water all charged to the American Elevator Company, thereby robbing the department to the detriment of the small user of water. You are expending annually large sums of money in building

up water works, and you are giving the advantage to the large users of water. That evil, it seems to me, should be corrected by the adoption of a uniform system of charges for water to all consumers, say 4 cents per 1 000 gallons, or whatever is actually necessary to bring the receipts up to the present revenue, — even if the rates have to be overhauled, which may be necessary in order to treat all citizens alike. All citizens are equal owners in the water department, — I refer now to water departments under municipal ownership, and this may not apply to private ownership, — and being equal shareholders in the plant, all are entitled to the same treatment. The United States government does not sell stamps to one man for a less price than it does to another. A man who buys $1 000 worth or $10 000 worth of stamps pays at the same rate as the man who buys only one stamp; and the same treatment ought to be accorded to all citizens who use the public water supply.

And for further proof of my statement, I will cite to you the fact that the municipal lighting department of Holyoke, which has lately acquired a plant from private ownership, charged for lighting on a basis of rates similar to those that are now charged for water, which I think is entirely wrong. If a man used $100 worth of electricity in a month, he got a discount of 60 per cent.; if he used $50 worth, he got 50 per cent. off; if $35 worth, 40 per cent., and for $10 worth, 20 per cent. off. These discounts I contend were entirely wrong; and public opinion was aroused, and sounded such a protest against this discount system, which was to the benefit of the large consumer as against the interests of the small consumer, that this month the manager has announced that on and after December 1, instead of charging 25 cents per 1 000 watt-hours, the rate will be 12 cents to all consumers of electricity, less a discount of 2 cents, making a flat rate of 10 cents per 1 000 watt-hours. And I contend that the same principle should be endorsed by the New England Water Works Association and recommended to be applied to water. The present system encourages the fostering of trusts, because by combining interests they get their water much cheaper than they could individually, to the disadvantage of the small user.

I attended this meeting with the expectation of hearing the

report of the Committee on Meter Rates and to hear what members might say upon the subject. This is what I have to offer, and it is my intention to have adopted by our water board, if it is possible, the ideas which I have expressed.

MR. DESMOND FITZGERALD.* For one, Mr. President, I wish to say that I have been much delighted to hear such sentiments as Mr. McLean has expressed, and to hear them so well put.

MR. MORRIS R. SHERRERD.† May I ask Mr. McLean if he proposes to couple with his uniform rates for metered water a minimum rate for service?

MR. MCLEAN. Our rate for metered water is, as I stated, where the monthly consumption is 50 000 gallons or less, 12 cents per 1 000 gallons. Now you can see the injustice which results to the small consumer. The large consumer gets all his water at the 4-cent rate, and we are building reservoirs, you might say, for him, while the smaller consumers pay 12 cents per thousand gallons. For the first 50 000 gallons the charge is 12 cents, for the next 200 000 it is 8, and for over that, 4 cents.

MR. SHERRERD. Must the consumer pay a certain minimum amount in order to get the water at all?

MR. MCLEAN. Yes.

MR. SHERRERD. How much is that a year?

MR. MCLEAN. If he only uses 50 000 gallons a month or less, the rate is 12 cents.

MR. SHERRERD. What is the least possible charge that a family could get through on? Is it $2 or $3 a year, or something of that kind?

MR. MCLEAN. All faucet charges are at a stipulated rate, and families pay a stipulated price, $3.60 a family per year, *net*.

MR. SHERRERD. Without meters?

MR. MCLEAN. Without meters; the idea is to encourage the use of meters and make the price as nearly equal to all as possible, by having a standard rate for all water, whether a man uses one thousand gallons or a million gallons.

MR. HOLDEN. Does the city furnish the meter, or the consumer?

* Consulting Engineer, Brookline, Mass.
† Engineer and Superintendent Water Department, Newark, N. J.

Mr. McLean. The city.

Mr. Sherrerd. It seems to me that there are two elements which enter into the cost of water; one is the water itself, and the other is the cost of the plant to distribute the water. I have gone into the question pretty thoroughly, and although the speaker who preceded me may perhaps be right theoretically, yet it seems to me there must be a fixed amount paid by each consumer before he begins to pay for the water. On the Newark, N. J., plant that amount figures $4 on each tap. This represents the interest charge on the cost of the distribution system; that is, it costs the city $4 a tap before a single gallon of water is delivered to the consumers. If you have a 25-foot lot, and you take water for your house by meter, you may get through, at our rate, for from $8 to $10 per year. Your neighbor may have a 25-foot lot on which he has a factory, and he uses, we will say, $100 worth of water. Now it practically costs the city the same amount of interest on the plant to bring the water of the small consumer, who only pays $8 to the city, that it does to bring it to the large consumer, because the mains have got to be large enough for fire protection in any event, whether that consumer is there or not. And it seems to me that this situation ought to be taken into consideration when the question of fixing rates comes up.

Then to prevent meter consumers combining to get larger discount, it would seem to me that a water department, particularly a municipal department, could control this by making the sliding scale apply to each meter or to each building, and thus prevent any combination of interests, scattered all over the city, from getting the benefit of the large reduction in price. I know that with us it would be a pretty serious thing if we were to raise the rate to our large consumers. I agree that it is nice to talk about making the rate as low to the small consumers as to the large ones, but if we should not give a reasonable discount, so as to bring the price of the water down, our larger consumers would be able to get an adequate supply of water for their cooling purposes, and satisfactory for all but boiler use, by taking it from driven wells. If we should attempt to make a uniform rate, I know that we would lose a large portion of factory con-

sumption, and I think the same thing might be true in other localities.

Mr. McLean. I would say that for all services that we put in we charge the consumer as far as the curbing on the sidewalk. If a man owns four hundred tenements, he is charged $3.60 a year for every faucet, every tap in every tenement, while the readings of meters belonging to the large corporations are added together, thus bringing the price to the lowest rate.

Mr. Sherrerd. Put him on a meter.

Mr. McLean. His tenements are distributed all over the city, and he pays $3.60 a year for each tenement; while the consolidated interests, which meter their water, as I have before cited, get the benefit of the low rate. All their meters are read as one meter. It is impossible to read every meter on its own basis, because that would put the rates up, unless the rates were changed. The only fair and just way, under municipal ownership of the plant, to all the citizens, who are equal owners in the plant, is to make a flat rate as low as possible; just as the United States government makes its rate on postage stamps, or its duties, or anything else, the same rate to each and every individual. Consequently, I contend that it is the duty of all municipalities to charge a flat rate of so much per 1 000 gallons.

Mr. Robert J. Thomas.* I think, Mr. President, that it is the duty of a municipality to furnish water to its citizens at the lowest possible rate, — to furnish a first-class quality of water and plenty of it, at the lowest possible rate. Now, it seems to me that if by reducing the price of water the municipality can increase the number of takers, and thereby increase the revenue, it will be able to furnish to all the citizens water at a lower price than would be possible otherwise. As Mr. Sherrerd has well said, a great many large water takers would put in pumps, drive wells, or take water from other sources, and thereby deprive the city of a large revenue, if they did not receive an inducement in the way of reduced rates for a large consumption.

The highest rate in Lowell is 14 cents per 100 cubic feet for the first 20 000 cubic feet in a quarter; for the second 20 000, the charge is 13 cents; for the third 20 000, 12 cents, and so on, the

* Superintendent of Water Works, Lowell, Mass.

lowest rate being 10 cents. But we do not give water takers the benefit of that sliding scale, except on a single meter. If they have two meters or more, they are charged separately for each meter.

One of the benefits to be derived from a sliding scale, and I presume it was one of the motives for establishing it, is that instead of having three or four services for one piece of property, thereby increasing the cost of maintenance to the water department, they get along with only one pipe and one meter, decreasing the number of services and the number of meters and consequently decreasing the cost of maintenance. I can't see the necessity, in Holyoke or in any other place, of taking all the meters of one concern, considering them as one account, and giving them the benefit of the sliding scale. That is, it seems to me unnecessary, and is not the practice throughout New England. It certainly is not the practice in Lowell, and I believe we follow the general practice pretty closely.

Another reason for the adoption of a sliding scale is that the more revenue you can get from your plant the easier it will be to reduce your rates to all water takers. Of course, the question has two sides to it, and it will bear discussion and looking into. I feel that it has not been discussed as much as it ought to be by the Association, and that it is very opportune to bring it up to-day. Mr. McLean has done good service in calling it to the attention of the Association, and it ought to be further discussed, for to my mind it is not by any means a settled proposition that it is the duty of a municipality to furnish all its citizens with water at the same price, regardless of quantity used.

Mr. Coggeshall. Do you have a minimum rate for meters, Mr. Thomas?

Mr. Thomas. We have a minimum rate of $7.

Mr. FitzGerald. It has often struck me, Mr. President, that this idea which Mr. McLean has advanced runs through all our systems of business. If I go to a railroad station and wish to go to Newton, and I can afford it, I buy a package of tickets, so that the cost of my trip is very much reduced; whereas a poor woman, who is only going out there once, perhaps, has to pay nearly twice as much for her trip as I do. It seems to me that

in the case of a public carrier that is all wrong. In this particular case it costs the railroad just as much to carry me as it does to carry her, and I think we should pay the same.

This is a subject which I have thought of a good deal — in fact I believe I am on a committee which has been appointed in an adjoining municipality to consider this very subject — and I believe, as my friend Mr. Thomas says, that it is a question which has two sides; and I think it will be an excellent thing for the Association to take it up and make a business of discussing it. I am sure that the varied experiences and opinions of our members would make the discussion exceedingly interesting.

Mr. McLean. While I have a good deal of respect for the views which other members have expressed, and I think there is a good deal of justice in their contention, I am still of the opinion that the only fair way is to have an equal rate for all. Where municipal ownership has been made a success, equal rates have been charged to all for the product of the municipality, whether gas or light or water or anything else. In New Zealand the railroads are under public ownership, and it doesn't make any odds whether a man ships 1 000 tons of freight or 100 pounds, his shipment goes at the same rate; and so, under municipal ownership, water should be supplied at the same rate to all citizens. It is not the same as with private ownership. A private company can do what it wants to, but under municipal ownership every individual is a part owner of the plant, and he should have equal rights. Realizing that, the Holyoke lighting department, which is the only municipal department of its kind in the state on a large scale, will supply the citizens at a uniform rate in the future; whereas previous to the adoption of the new system many were getting 60 per cent. off, while the small consumer was getting only 20 per cent. off. There is no justice in operating a municipal department for the benefit of the large consumer, as we are now operating the municipal water department, building reservoirs and borrowing and expending large sums of money in laying pipes to supply his needs, and giving him water at the very lowest rates possible, three times lower than others. I contend it is the duty of the municipality to supply all of its citizens with water at one price, and if the large consumers refuse

to take it, well and good. But I don't believe they will. I know of no large user of light or power from the electric department who has stopped taking it since the change of discounts, and so with the water; I believe with a flat even rate to all we will still be able to furnish water to all cheaper than they can procure it for themselves, and of a better quality.

Mr. Robert Spurr Weston.* I should like to ask Mr. McLean if the present minimum meter rate at Holyoke is less than the cost of furnishing water?

Mr. McLean. I cannot answer that correctly at present; we are now installing four large meters, — two Venturi and two Premier, — which will show our hourly and daily total consumption; then we can come very near to knowing exactly what we are doing.

Mr. Caleb M. Saville. May I ask Mr. McLean if he advocates a universal meter system?

Mr. McLean. I do; yes, sir.

Mr. Saville. On everything?

Mr. McLean. I do. I think it is only a question of time and enlightening the citizens as to the advisability of using meters. It is a hard task to do it, but the time is coming when they will see it. We all know from experience with faucets and fixed charges that the leakage is enormous. Sometimes a ¼-inch opening may run half the year without our knowing it, and leaks are occurring all the time. If all services were metered it would be better, and it would not take as much water to supply the municipality.

Mr. Merrill. I do not know whether Mr. McLean attended the meeting, or read the preliminary report of this committee which was presented in the spring, but if so he will recall, undoubtedly, that the statement was made at that time that the city of Somerville had looked at the matter in much the same light that he does, and so far as it was able had placed the metered water charges on a uniform basis, abandoning the sliding scale which had formerly existed, of 14 cents for the first 20 000 cubic feet used in a quarter, 13 cents for the second 20 000, and 12 cents for the next 960 000 and 8 cents for anything over a million, and

* Sanitary Expert, Boston, Mass.

substituting therefor the uniform rate of 12 cents for 100 cubic feet.

I will not say that that was made to apply to every consumer, because we have, I think, three out of our 11 000 rate-payers who use water in so large quantities that it was deemed inadvisable to increase their old minimum 8-cent rate to the otherwise uniform rate of 12 cents. Conditions must decide whether the uniform rate can be made to apply to all cases. One of the companies to which I have referred has a local water plant of its own now, and I think there is no doubt that if such an increase in its water charges as would result from advancing its minimum 8-cent rate to a uniform 12-cent rate had been made, we should have lost a considerable portion of its patronage. But with these exceptions we are on the uniform basis of 12 cents per 100 feet or 16 cents per 1 000 gallons; and I am inclined to agree with Mr. McLean that, where circumstances will permit, that is the proper way to charge for water.

Mr. Charles W. Sherman.* One of the companies with which I am now connected has found itself in a situation very similar to that described by Mr. Merrill. In the city in which it operates is a very large plant belonging to one of the so-called trusts, which employs a large percentage of the men of the place. Formerly, with the water supply under a different management and partially under the control of the municipality, that concern was allowed to have water free. A new management having taken hold of the water plant, an attempt was made to put the rate up to that paid by other consumers; I do not pretend to say it is a flat rate, however theoretically proper such a rate would be, but to what any one else would pay for the same quantity of water. It was found to be absolutely impossible to do that, for if it were done the plant would be closed and the business moved out of town.

Now, in my opinion, the theoretically proper way to get over that circumstance would be by receiving from some source the same sum of money that another consumer would have paid for that quantity of water; and the balance in excess of what the plant could afford to pay in that location should be made up by

* Assistant Manager Water Companies, Boston, Mass.

general taxation on the municipality, and not by increasing the water rates to other consumers; that is, by making the whole municipality and not the water-takers stand the difference. That was a case where it would have been suicide for the water company to establish a rate such as would force the manufacturing plant out of town, since it would have practically killed the municipality; and the result was that a rate was made substantially covering the cost of the water, possibly a fraction of a cent less than the cost to the company — and of course the balance has to be obtained out of the other water consumers. It is not right, but I do not see how we can do any better.

Mr. Sherrerd. May I go a step further, Mr. President, with what I said on the subject when I was speaking of the lots? I forgot to mention that there is another factor which should be taken into account, and that is the vacant lot in front of which a pipe is laid. That lot gets the benefit, as all the real estate in the city gets the benefit, from the large pipes for fire protection. But I know that in some cities — and one I know positively about; that is, Troy, N. Y. — they charge in the tax levy, and it goes in the tax bill on the real estate, $5 on a 25-foot lot for every lot in front of which the water pipes are laid. That is really equivalent to taking care of this item of $4, which I spoke of before; and perhaps it is, from a theoretical standpoint, a fairer way to distribute the cost of the distribution system upon the real estate. Of course this always raises an objection on the part of large owners of vacant land, but I know that in the development of such tracts of land these same owners are anxious to have the water department, or the water company, lay water pipes through the streets on which the lots abut, because the lots are thereby increased in value and brought into the market. And if that is true, if the pipes of the water department increase the value of the real estate, it seems to me that the real estate ought to pay a portion of the fixed charge, and that would leave the way open for the establishment of some uniform rate for the water.

Mr. McLean. If the Association is ready at this time, I would make a motion that it is the sense of this meeting that we adopt some kind of a system such as has been suggested.

The President. I think, Mr. McLean, that, pending the report of the committee, it would hardly be advisable at this time to take any action. The committee has the matter under consideration and has merely reported progress, merely outlining some of the points that have come up in the minds of the committee as to the many difficulties there are in the way of fixing a uniform meter rate.

Mr. McLean. Each city, of course, has its own problems in that respect, but I think the nearer to a uniform system the Association could adopt, the better it would be. The way we in Holyoke get over the difficulty that my friend on the left [Mr. Sherrerd] suggests is by taxing the fire department so much for every hydrant that it has. It pays us, I believe, $8 a year for each hydrant. I suppose we all have our different ways of doing these things, but the more uniformity there could be about it, it seems to me, the better it would be.

WATER TANK AND TOWER FOR EAST PROVIDENCE, R. I.

BY F. M. BOWMAN, STRUCTURAL ENGINEER, RITER-CONLEY MFG. CO., PITTSBURG, PA.

[*Read November 9, 1904.*]

During the fall of this year the East Providence Water Company completed its new water tank and tower at East Providence, R. I., and as the structure is in several respects the largest of its type, a description of it in detail will, no doubt, be of interest.

The tower is 135 feet high from base of column to base of tank, and the tank is 50 feet diameter by 70 feet high, with a capacity of 1 000 000 gallons. The height from the base is therefore 205 feet for water pressure, and the total height to the top of the finial is 234 feet. The structure, a view of which is shown in Plate I, makes a water reservoir for fire protection for East Providence and Riverside, R. I., it being located on an elevated point about half way between the two places; the pumping station, however, is located some three miles from the site of the tower.

For ten years previous to the completion of this structure these cities were supplied with water directly from the pumps, there being no reservoir of any kind. The pressure now obtained is great, and the residents find it necessary to look carefully to their plumbing.

Referring to the details of design, it is to be noted that the tower has four center and eight outside columns, as shown in Plate III, Fig. 1. Most of the direct load is carried on the four center columns, each column carrying, approximately, 700 tons. The location is such that the foundations are carried to solid rock, making ideal construction. The foundations are of concrete, except that a granite cap stone in one piece is used under each of the twelve columns, — in the case of each center column this cap stone being 3 feet × 6 feet 6 inches × 6 feet 6 inches, and weighing 11 tons. The lower section of this column weighs 12

tons, exclusive of cast-iron base (Fig. 1) and consists of two web plates 15 × $\frac{3}{4}$ inches, four flange angles 6 × 6 × $\frac{11}{16}$ inches and four cover plates 24 × $\frac{11}{16}$ inches.

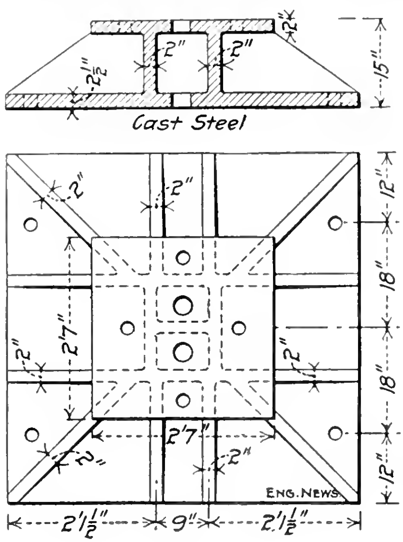
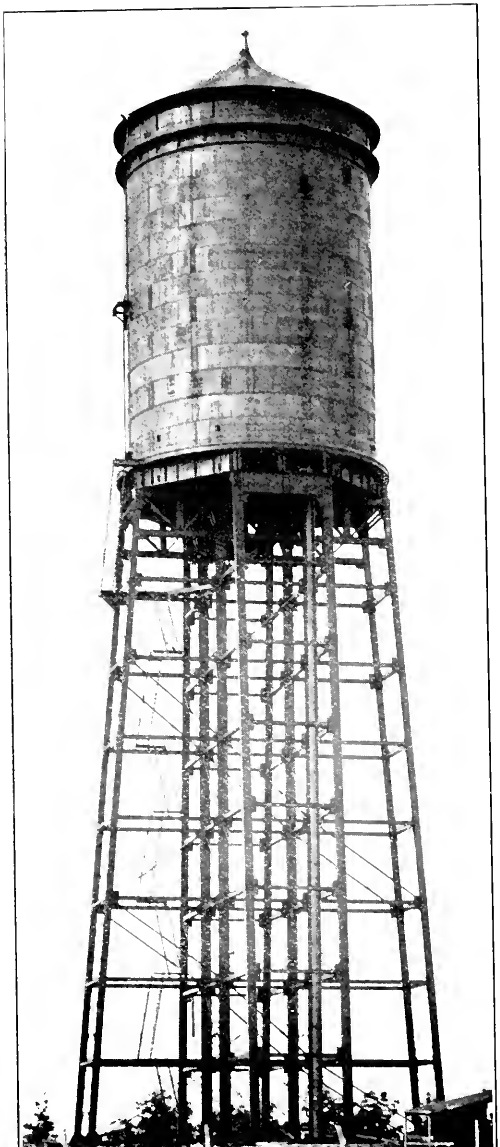


Fig. 1.

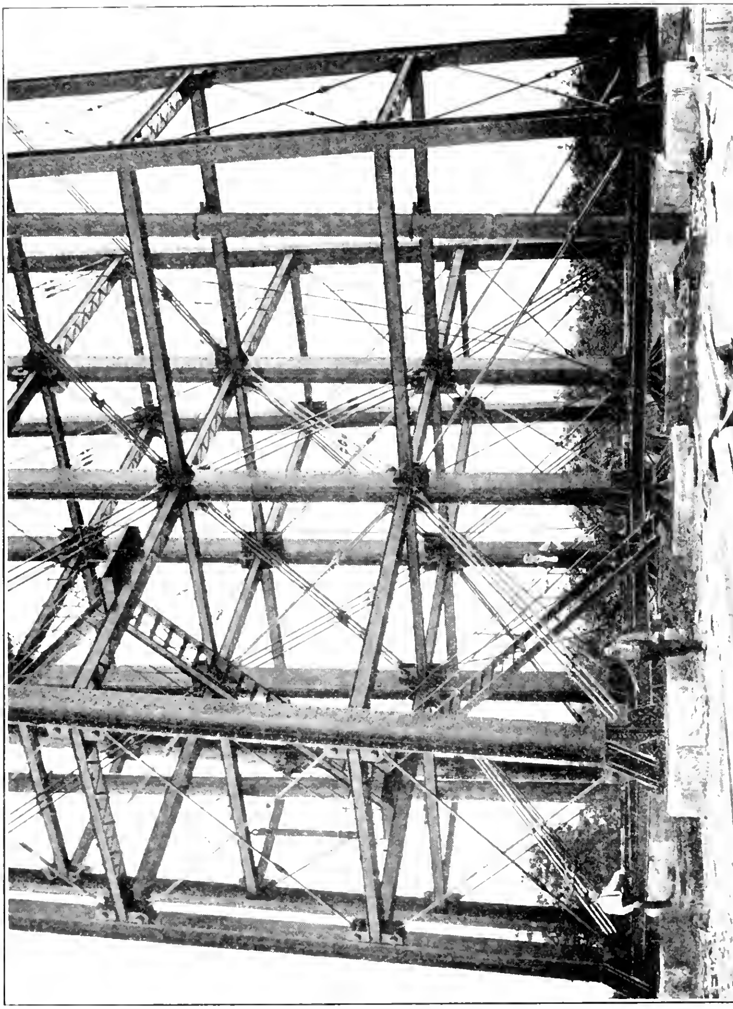
The wind pressure was figured at 50 pounds per square foot of exposed surface for the tower, and in the case of the tank the pressure was assumed as two thirds of this load on the diametrical area instead of the usual one half. The horizontal wind strains from the tank are carried almost entirely by the eight outside columns, which act as the top and bottom chords of a cantilever girder with panel points at every third horizontal strut, the cantilever being fixed to the ground by the anchor bolts.

The floor beams for the platform are 12-inch I-beams, carried on box girders spaced about 9 feet on centers, these in turn being carried on pin connected girders; the load from the box girders is transmitted by direct bearing to the center post of the pin connected girders. The platform itself is made of concrete 16 inches thick, thus making the bottom of the tank frost proof and protecting the lower surface of same from rust. The concrete is extended to the hand railing along the edge of the platform and forms a foot-walk around the tank.

The bottom of the tank is of $\frac{1}{2}$-inch steel plates; the sides vary in thickness from $\frac{15}{16}$ inch for bottom ring to $\frac{3}{8}$ inch for top ring. The horizontal seams are lap joints with two rows of rivets $\frac{7}{8}$ inch in diameter for the lower rings; the upper seams have one row only with $\frac{3}{4}$-inch rivets. The vertical seams are butt joints for the lower eight courses and lap joints for the upper six. The butt joints have two splice plates, the inner one about twice as



EAST PROVIDENCE WATER TANK AND TOWER.



FOOTINGS OF COLUMNS.

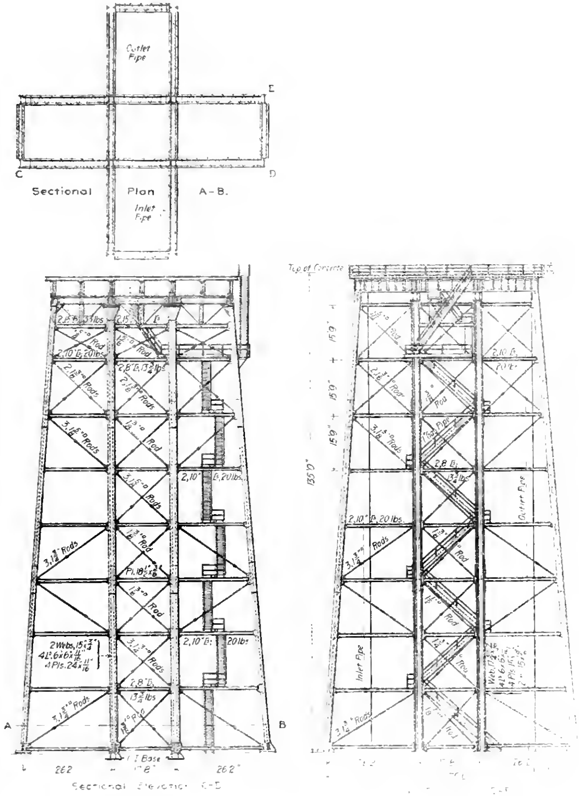
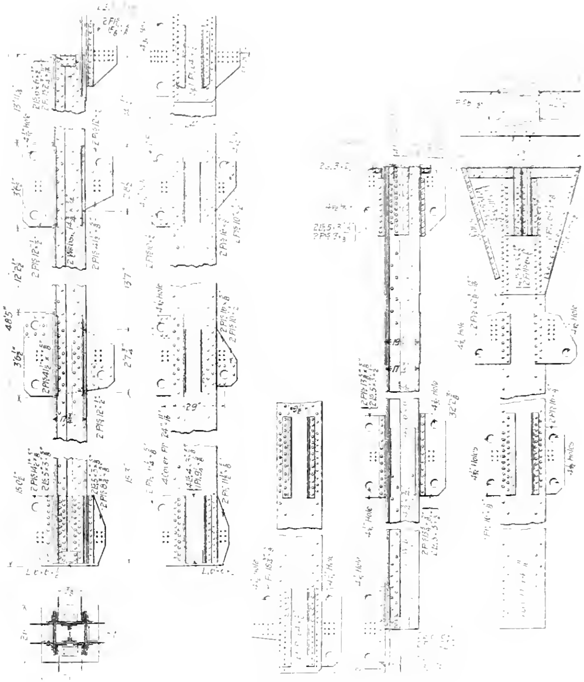


Fig. 1



Details of Columns.

wide as the outer to increase the percentage efficiency of the joint. The diameter of rivets varies from 1 inch for the lower ring to $\frac{3}{4}$ inch at the top. The tank is anchored to the tower with eight bolts 2 inches in diameter connected to the lower course of side plates and to the web plates of supporting girders.

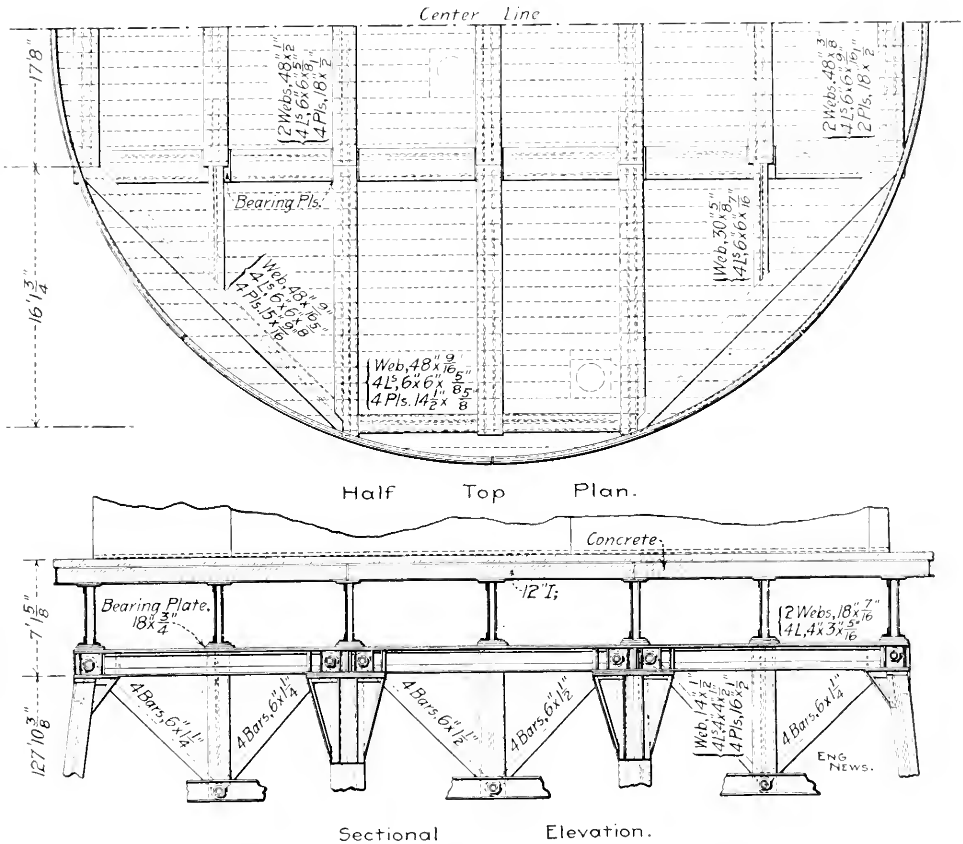


FIG. 2.

A balcony is provided around the side at the top of the tank. An opening 30 inches deep is allowed between the top of the shell and the roof line for ventilation, the opening being covered with heavy wire screen. The roof consists of $\frac{1}{8}$-inch plates riveted

together and supported on steel trusses, the finial being a 24-inch copper ball.

The inlet and outlet pipes are $14\frac{1}{4}$ inches inside diameter, of steel pipe supported on suitable foundation in a pit where the gate valve is located; they are attached to the tower by steel ties at the cross struts, and a slip joint is provided at the top section for expansion. Steel flanges are used for pipe connections and the pipe is covered with three inches of asbestos, this being in turn protected by a sheet metal cylinder $\frac{1}{8}$ inch thick, made in halves, with flanges projecting outward for bolting the sections together.

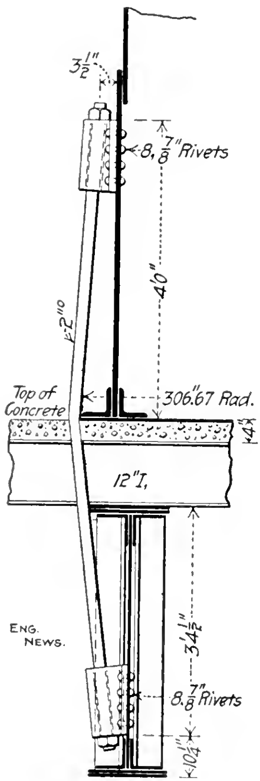


Fig. 3.

Stairs 30 inches wide are furnished to base of tank; the tank is provided with a vertical ladder 15 inches wide with a balcony half way up the tank as a rest. A separate stair is also provided to the manhole in the bottom of the tank; this manhole, 16 inches in diameter, being for access to inside of tank for cleaning and painting.

The material of the tower is medium, and that of the tank soft, open-hearth steel. The structure is designed with a factor of safety of four, the tension unit strain in tower being 14 000 pounds and in tank 11 000 pounds per square inch. The pressure of the column bases on the granite caps does not exceed 400 pounds, and that of the granite on the concrete 250 pounds per square inch.

The erection had to be carried on carefully on account of the great height and the prevalent high winds, and the work was slow and expensive for these reasons and because it was impossible to carry on the raising of material and the driving of rivets at the same time. The raising of material had to be abandoned

when the riveting was in progress, as otherwise the riveters were liable to accident and injury. The work was carried on under the supervision of the engineers of the Water Company, Messrs. Bushnell and Wood, the Riter-Conley Manufacturing Company, Pittsburg, Pa., being the contractors.

DISCUSSION.

Mr. Arthur B. Lisle.* The situation is just as Mr. Bowman has stated in his paper, and the only thing which occurs to me which perhaps would be of an additional interest to the members of the Association is a statement of some of the reasons for putting up such a standpipe, and the advantage that we hoped to gain thereby. We have no other reservoir, and being practically forced by the demands of the insurance people to have some reserve in case of fire, — for although we have duplicate pumping apparatus, in case of accident during a fire that would not be of enough assistance, — we were practically forced to put in a standpipe. Our reason for putting in one of such size and type was to give us a pressure which would be satisfactory to all interests. This standpipe will give us a pressure of 150 pounds at tide water, and as much of our territory is near tide water, and our largest business, especially our manufacturing business, is all near tide water, we will get 125 to 140 pounds pressure for almost all of our large customers. That pressure will be of more or less assistance to us, not only from the fire protection standpoint but from the commercial standpoint, by enabling us to get business from manufacturers; because this pressure will obviate the necessity of using feed pumps, injectors, etc., and it will allow the feeding of boilers direct from the system. It has already worked to our advantage in that way.

The standpipe is large enough for the territory we have to furnish and to take care of any ordinary fire demands. We could get along with the standpipe for possibly a day and a half in case anything should happen to our pumping apparatus, and although it is not a large system and the amount of water is not very great, the standpipe puts us in a position where we are so much better

* Treasurer, East Providence Water Co.

off than we were before that we feel quite pleased. We had some trepidation because we feared that the high pressure might cause a lot of trouble on our mains, as previously we had never had much over 80 pounds. But during the last five years, anticipating this change somewhat, we have laid only the heaviest pipe and have tried to make the joints such as to avoid trouble of this kind. The standpipe has been in service now for nearly a month, and we have had no breaks, other than the blowing out of a couple of dead ends where there was probably some water-hammer.

PRESIDENT E. C. BROOKS. Would you care to tell us approximately what the structure cost, Mr. Lisle?

MR. LISLE. I do not think it would do any harm to say that it cost a little less than $100 000.

MR. FRANCIS W. DEAN.* Mr. President, I have from time to time taken some interest in the designs of towers for this purpose. I note that there is an angle-iron at the bottom on the inside as well as on the outside, as is usually the custom. The method of placing the angle-iron on the outside only is very bad construction, and I think it is in a measure responsible for some of the failures which have occurred. The angle-iron would necessarily be quite large, — I suppose it is frequently 6 × 6 inches, and as the rivets therein are near the outer edge, in order to be able to calk the joint properly, you will see that under this angle-iron there is quite a width of plate, where there is an upward pressure. The weight of the tower itself, that is, of the outside shell, resists it, but nevertheless there is an upward effort due to the water pressure, which amounts to a great deal, and which tends to bend the bottom plate. Such bending undoubtedly takes place at times, especially when there is a heavy wind; and it acts on the plate just as a lap joint on the longitudinal seam of a boiler acts. A lap joint on the longitudinal seam of a boiler is responsible for nearly all boiler explosions, because the lap joint, being stiff, and the shell being out of round due to the lap, it bends at the edge of the lap, with changes in pressure, and finally starts a crack. A great many boilers have cracked enough to let a little steam through and thus have given warning. Similarly the bottom plate of a standpipe after bending under the angle can very easily

* Mechanical Engineer, Boston, Mass.

rupture, and in many cases the only thing which holds the standpipe down is the weight of the water on the bottom.

If the angle-iron is on the inside, so that the calking is on the inside and no water pressure can get under the angle-iron, this source of rupture cannot exist.

The drawing also shows that the tank is held to the platform by means of bolts on the outside, going up some distance on the outside, and taking hold of the shell. Now, as matter of fact, they should go up a long distance, and no dependence whatever ought to be placed on the weight of the water in holding down the bottom. The resistance to the tower's overturning should come from these bolts and they should go up sufficiently far to make the outside act as a vertical girder, so as to distribute the pull which may come on the bolt.

Moreover, I think that such tanks should be so strongly braced on the inside that they become very stiff. I think one great trouble with standpipes has been that they have been too limber; the wind has too great an opportunity to bend them in and work them back and forth. Of course, where a tower is roofed as this is, and the cover is fastened, it receives therefrom some degree of rigidity at the top; but I think, as I have just said, that towers of this kind should be made thoroughly rigid throughout. In fact, it has sometimes seemed to me as if there ought to be some vertical and circular girders on the outside or inside, to make the structure absolutely rigid.

Mr. Morris R. Sherrerd.* Mr. President, I should like to ask a question, for my own information more than for anything else. I have understood that some failures of standpipes have occurred by reason of the mass of ice that forms in the upper portion acting somewhat as a piston. As the water is drawn down from under three or four or perhaps five feet of ice in the top of the standpipe, it leaves an air space, and then the action of the sun on the sides of the standpipe loosens that plunger and allows it to come down on the water, thus creating a hammer that would tend to explode the pipe. I think perhaps you New England people have had more experience in standpipe construction than some of us around New York have had, and I would like to ask

* Engineer and Superintendent, Water Department, Newark, N. J.

whether it would seem advisable to have some construction in the upper portion of the pipe which will hold this mass of ice and keep it from dropping? I have thought that perhaps it might be well to have some cross-arms which would reach down 15 or 20 feet, perhaps 30 feet, from the top of the standpipe, to prevent this mass of ice from dropping.

THE PRESIDENT. Have you any information to give on that subject, Mr. Dean?

MR. DEAN. No, I have not. I have read more or less that has been written about the effect of ice, and have heard the subject discussed somewhat, but it never seemed to me at all a satisfactory explanation for the failure of a standpipe. We have all seen, of course, statements that the expansion of the ice would cause a rupture, but it seems to me that the expansion takes place so soon after the ice begins to form that the effect would be to crush the ice and not to rupture the shell.

MR. LISLE. I will state, Mr. President, that the conditions with us are very peculiar, and the possible trouble from ice is one of the things we are worrying about as much as anything else. We pump from a rapidly flowing stream. Last winter we took a lot of temperature observations during the cold weather, — and, as you know, it was very cold last winter, — and for days at a time we got a temperature in the river of 27 or 28 degrees. Now, when we pump that water into the standpipe, although it has to go through the ground for three miles, we are a little bit afraid it is going to freeze as soon as it gets there. I should like to know if any of the members have had any experience as to what is the warming effect on water of going through the ground for three miles, — whether it would be enough to raise the temperature sufficiently to overcome the danger of freezing.

THE PRESIDENT. I should like to know if any member has had any experience in regard to the temperatures of water which will be of any guidance to Mr. Lisle. I have never been able to get water even down to freezing in a hole cut through the ice in a pond, and it does seem as though Mr. Lisle's extraordinarily low temperatures were something new and novel. I have certainly never heard of anything of the kind. Do you know, Mr. Lisle, may I ask, whether the thermometer you used was standard?

MR. LISLE. I do not know of my own knowledge, but some tests were made last winter in anticipation of trouble from freezing, and that report was made by Mr. Bushnell. I do not know the details but will be very glad to procure them and submit them to the Association at some future time.*

MR. DESMOND FITZGERALD.† A number of years ago I was making some experiments at Chestnut Hill Reservoir, and I had a 16-inch pipe in the yard filled with water, in which was floating a copper ball which nearly fitted the pipe, so that there was only about half an inch of space all around. The copper ball was weighted so that only a very little of the upper part of it was above the water, so that the angle formed with the surface of the water was very acute. During the night the weather suddenly became very cold and the water froze about half an inch in depth around the copper ball and burst a hole through it. The thrust took place on an angle of about 10 or 15 degrees. This result will give an idea of the power of ice in expanding, and developed the fact that instead of rising or of crushing the ice that small depth of ice had crushed a hole through the heavy ball. You can imagine the power which was exerted.

While I am on my feet, I will say a single word in the cause of an artistic treatment of standpipes and towers, and all other works connected with municipal water supply. I think members of our profession, engineers and water-works superintendents, are too apt to overlook that side of the matter. A very little additional care in regard to the proportions of these water towers, and to building them so that they will present an artistic effect, will make all the difference in the world. I am not speaking of the East Providence tower particularly and wish to make my remarks general, but I think it is a good plan for all of us who design such structures to keep in mind, first, the correct proportioning of the

* Since the above statement was made, I have investigated the tests made as to the temperature of running water and find that although the thermometer was standard and probably approximately correct, the tests were not made in a strictly scientific manner, *i. e.*, the thermometer was immersed in the river but was not read under water, so that although it was read as soon as possible after being removed from the water, the air temperature being about zero, the thermometer probably dropped two or three degrees between the time of being removed from the water and being read.

† Consulting Engineer, Brookline, Mass.

parts, and secondly, an artistic treatment of the design so as to make it attractive.

THE PRESIDENT. Wouldn't you apprehend, Mr. FitzGerald, that such a condition of things as that spoken of by Mr. Lisle would be very apt to show itself in the formation of anchor-ice?

MR. FITZGERALD. I don't know that I can answer your question, Mr. President, but I will say this, that I have made a great many observations on anchor-ice, particularly with the thermometer. In regard to the temperature of water just under the ice I have found that it is at the freezing point, or even at times slightly below it, but that temperature extends to a very slight depth. It is governed by the temperature of the air above the ice. Below that it is influenced by the temperature of the water, but directly under the ice you will get the temperature of freezing. The effect of freezing can be studied by placing some water in a pan and putting a thermometer in the water so it is entirely immersed horizontally. If it is a very accurate thermometer with graduations so wide that one can read to a tenth of a degree, it will be found that as the water gets down to the freezing point it will suddenly go below the freezing point about one degree before the ice begins to form, and the instant the ice begins to form as shown by the presence of little crystals of ice, the thermometer goes up again to 33 degrees. The heat is liberated by the action of freezing.

In regard to anchor-ice, I have always found that anchor-ice will form only when the whole mass of water in the pond is cooled down to 32 degrees and there is a wind; but if it is quiet, and the crystals begin to form at the surface, we do not have any anchor-ice.

MR. DEAN. I had an interesting experience some years ago, Mr. President, in regard to the temperature of water, and your asking if the water ever got to the freezing point reminds me of it. I was testing an engine at the Atlantic Mills in Lawrence. The water came from the Essex canal to the condenser, and as I wanted to know the temperature of the condensing water I had a hole drilled in the pipe and a tube inserted, and in that tube I put cylinder oil and placed a bare stem thermometer. After a while I saw that the thermometer registered just exactly 32

degrees. I supposed that the thermometer was not right, and I went and got another one made by either Green or Queen, I have forgotten which, — the first was a Huddleston thermometer, — and that also registered 32 degrees after a while. Then I put in still a third, and that registered 32 degrees. It was a great surprise to me to find that water coming from the canal would stand at 32 degrees, but after three thermometers, made by different makers, showed it, I thought it must be so.

Mr. R. S. Weston.* I have observed the temperature of water in natural rivers as low as 32.3 degrees, with floating ice in the stream. Another point I may mention, that it is possible to cool water down to between 30 and 31 degrees Fahrenheit, provided the water is kept perfectly quiet, but the slightest movement will cause the ice crystals to form and freezing will take place. I have cooled water down in a special apparatus and then slapped the surface of the water and seen it freeze in that way.

The President. My only reason for asking about Mr. Lisle's observations was that I have always understood that water could be cooled below freezing provided it was kept perfectly quiet, but that if there was any motion to the water ice needles would form immediately.

Mr. M. F. Collins.† I would say that at Lawrence we take the temperature of the water every day in connection with our filter, and 32 degrees is the lowest we ever get through the winter. After the water gets down to that temperature it stays at about the same for a month or two, but we never get it any lower.

The President. At what depth do you take the temperatures?

Mr. Collins. Probably two or three inches below the surface of the water. In passing to the pumping station the temperature of the water generally goes up two or three degrees. The water at the faucets has an average temperature of 43, 44 or 45 degrees throughout the winter.

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* Sanitary Expert, Boston, Mass.

† Superintendent of Water Works, Lawrence, Mass.

REPAIRS TO THE LINING OF A SMALL RESERVOIR ON POWDER HORN HILL, CHELSEA, MASS.

BY CALEB MILLS SAVILLE, DIVISION ENGINEER, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read November 9, 1904.*]

What I have to present to you to-day should hardly be dignified by the name of a paper; it is rather a collection of notes on a small piece of work recently carried out on the Metropolitan Water Works.

Records of small undertakings are frequently of considerable value because, while they deal most often with matters in the line of maintenance, very little information can ordinarily be found concerning methods and cost of such work, and the data from larger works of similar character are usually not applicable. On this account the following description of some work in Chelsea is presented, not because of its difficulty, but because it is in line with work that any water-works man may expect to encounter, and the data given may be useful for purposes of comparison.

In connection with the high-service supply of Chelsea, Mass., is a small reservoir on Powder Horn Hill, holding about 1 000 000 gallons of water which is supplied from the high-service system of the Metropolitan Water Works.

The shape of the reservior is shown by the plan, Fig. 1. The top is 178 feet long, over all, and 98 feet wide; the bottom is 148 feet long and 68 feet wide. The depth is 15 feet, and the slope of the sides about 1 to 1. It is built partly in excavation and partly in fill, the material being unstratified glacial drift containing such a proportion of clay that it was excellent for building a reservoir bank.

The original work was done by Trumbull and Cheney in 1887 for the city of Chelsea. On first filling the reservoir with water the leakage was very considerable, and the work was found especially defective at the junction of the stone and brick paving.

After considerable discussion concerning methods of putting the reservoir in proper condition, a coating of cement mortar

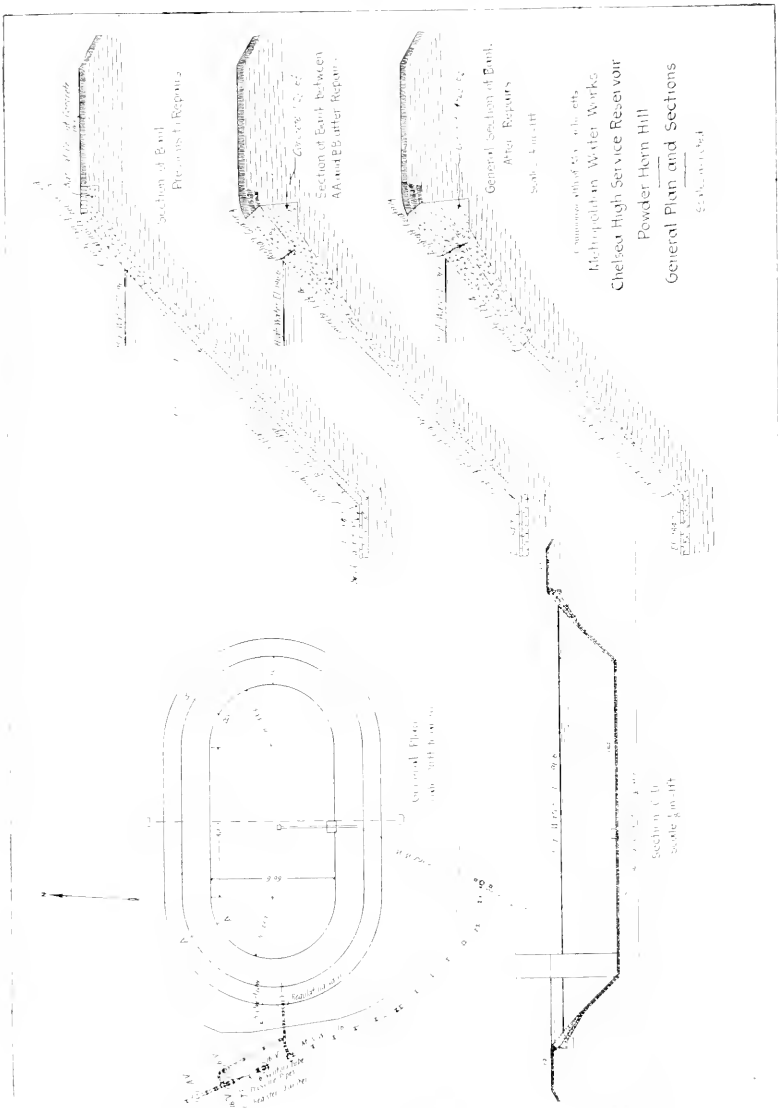


FIG. 1.

was finally applied to the whole of the inside slopes and bottom by a local mason.

No further trouble of serious nature developed until 1899, when horizontal cracks appeared in the lining on the slopes, due probably to frost action. This damage was repaired by filling the cracks and open places with cement mortar. In 1901 the cracks again appeared and were similarly stopped. When these cracks appeared for a third time, in 1903–4, it was realized that radical repairs were necessary. (Plate I, Fig. 1.)

In connection with these cracks it may perhaps be worthy of note that the greatest damage has always appeared on the south bank, and the cracks extended only partially around on the east and west ends, leaving the lining on the north bank intact and showing no defects. It may also be noted that at Forbes Hill reservoir, Quincy, the granolithic walk on the south side has twice been badly cracked, while that portion on the north bank has remained in good condition. The reason for this is not perfectly explainable, but the suggestion is offered that it may possibly be due to the action of the sun in winter and the intermittent thawing and freezing; while the north bank freezes more solidly and remains frozen until spring. In the work now to be described, the lining on the south bank was made somewhat thicker.

The work of repairing was done by the maintenance force of the Metropolitan Water Works under the general supervision of the engineering department. In undertaking the work the first consideration was of methods for economically moving the materials excavated and those required for concrete. The top of the bank was too narrow to allow the use of carts, and an 18-inch gage railroad was finally decided upon as most convenient. For removing the excavated material and depositing the concrete, a 65-foot boom derrick with a 70-foot mast was set up, together with a 15 horse-power double drum hoisting engine for working it. This derrick was held in place by six wire guy ropes; its reach was such that only one moving was necessary after it was placed.

The engine and derrick were set up on the floor of the reservoir, as shown in Plate I, Fig. 2, and the work of excavation

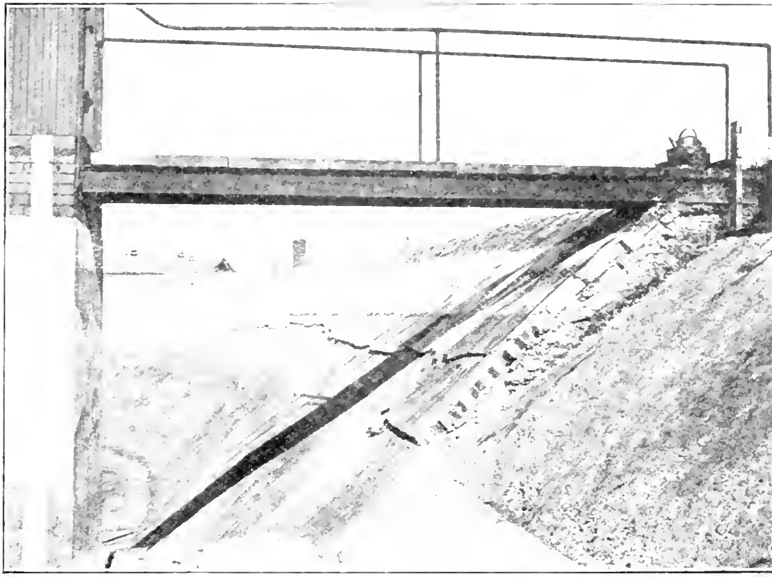


FIG. 1. CRACKS IN OLD LINING.

FIG. 2. PLANT EMPLOYED IN REPAIRING RESERVOIR LINING.

was begun at about the middle of the southerly side. In order to facilitate the work, a platform supported on "A" frames was set up. These forms were spaced about fifteen feet apart and rested on the bottom and slope of the reservoir, being held in place by bolts driven into the floor.

The paving blocks on the top of the slope were removed and piled up to be taken away; the old lining and the material excavated from the bank was shoveled into the scale pan of the derrick, hoisted to the cars on the top of the bank, and then run by gravity to a dump a short distance down the hillside. Here the cars were run out on a rough trestle, the load dumped, and the empty cars returned to the work by a rope carrried though pulleys to the winch head on the hoisting drum of the engine.

Two small portable storehouses were set up, — one 8 x 10 x 7 feet, the other 11 x 16 x 7 feet, — for the storage of some of the materials, but the bulky portions, such as cement, sand, and stone, were delivered as necessary, a few days' supply only being kept on hand. A branch from the railroad was so arranged that it passed the storehouses and stone piles, while the sand was piled close to the concrete mixing board. The intention on the work was to do nothing by hand that could possibly be done by steam, except that all of the concrete was mixed by hand. As great a proportion of water was used as could be done without causing the material to slide when rammed in place.

The lower layer of concrete was of the proportion by volume of 1 cement, $2\frac{1}{2}$ sand, and $6\frac{1}{2}$ crushed stone (sizes from $\frac{3}{4}$ to $1\frac{1}{2}$ inches). This was rather a lean mixture, and as it could not be rammed enough to flush all over, the surface was finished where necessary by a thick mortar made in the proportion of 1 cement to 6 sand, and applied with heavy brushes. Before placing any of the concrete, the bank back of the old concrete left in place was thoroughly rammed with iron railroad tampers, and the edge of the old concrete was scrubbed with water and a stiff brush and then coated with 1 to 4 grout, which was allowed to fill in the angle between the concrete and the slope. Just before placing the concrete the earth bank was well wet in order that moisture might not be drawn from the concrete while it was soft.

In order to make the new lining as water-proof as possible,

a layer of asphalt was placed on top of the lower layer of concrete and brought up on the exposed edge of the old layer at the bottom of the new work (Plate II, Fig. 1). This, it was expected, would make an elastic and water-tight joint between the new and the old work.

Venezuela asphalt, "Crystal Brand," was used, being poured upon the top of the concrete layer and allowed to run down the slope, care being taken that the concrete was entirely and perfectly covered. After the first layer of asphalt was cool, a second layer was similarly applied, and the resulting sheet was about $\frac{1}{4}$ inch thick. Any inclination to crawl down the slope when exposed to the sun was readily stopped by throwing on a pailfull of cold water. A most particular part of this work was to get the asphalt as hot and liquid as possible and yet not burn it.

All of the concrete was protected from the sun and kept damp by being covered with strips of burlap, which were moistened by sprinkling.

The upper layer of concrete was composed of a much richer mixture of concrete than that used in the bottom layer, the proportions by volume being 1 cement, $1\frac{1}{4}$ sand, $1\frac{1}{4}$ stone dust, and 4 broken stone (of the sizes mentioned above).

On account of the steep slope it was possible to do only a little ramming, and the material was laid as wet as possible. To make this layer more impervious and also to obtain a smooth surface, the concrete was left about an inch below and a finish coat applied by expert granolithic finishers. This coating was applied as soon as it was possible to do so after the main layer was in place, but on account of the steepness and the liability of the wet concrete to flow, care had to be taken not to begin work too soon. This was one of the most important parts of the work, on the one hand to apply the finish as soon as possible and make a perfect bond by working it into the moist concrete, and on the other hand, not to work on the layer soon enough to cause it to run, when it would perhaps have to be later taken out and replaced. (Plate II, Fig. 2, and Plate III, Fig. 1.)

The top finishing coat was made in the proportion of 1 part cement, $1\frac{2}{3}$ parts sand, and $3\frac{1}{3}$ parts stone dust. In order to help in bonding, the last ramming on the concrete was done with

FIG. 1. COATING LOWER LAYER OF CONCRETE WITH ASPHALT.

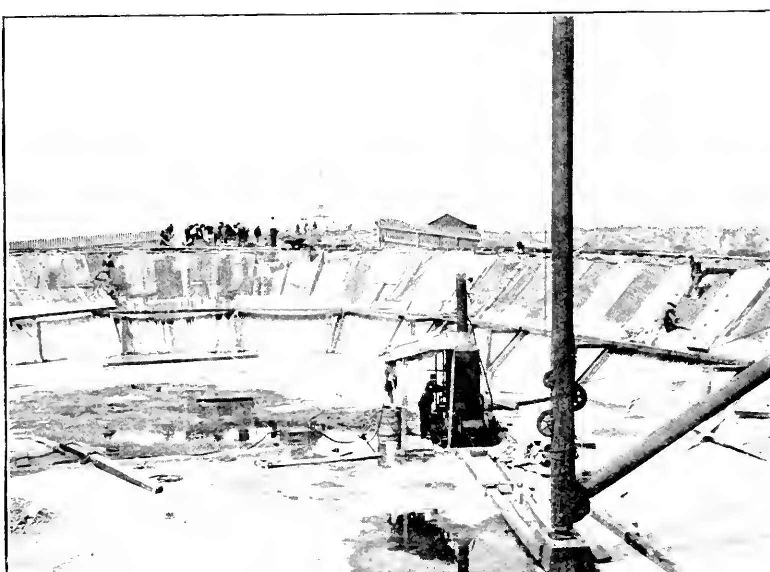


FIG. 2. LAYING UPPER LAYER OF CONCRETE.

FIG. 1. LAYING AND SURFACING UPPER LAYER OF CONCRETE.

FIG. 2. RESERVOIR LINING COMPLETED.

rammers studded with pieces of iron about one inch long and one-half inch deep. The finishing was done in three operations: first, the material was spread on the concrete and thoroughly worked into it by the finishers, using rough wooden floats; after this it was gone over and partially smoothed down with a thin steel float; and finally it was worked to give the finished appearance and an impervious surface.

The under layer of concrete was placed in a continuous sheet; the upper layer was put down in alternate strips, 10 feet long (the whole length of the layer) and 5 feet wide. These blocks were built up in forms, as shown in Plate II, Fig. 1, which were not removed until the concrete had set. Finally, the back or edge of the block toward the bank was well wet and thoroughly plastered, to prevent as far as possible the infiltration of any water which might freeze and thus cause damage to the concrete. The plaster was proportioned 1 part cement to 4 parts sand. When the forms were wholly removed, the space between the concrete and the bank was refilled to within about six inches of the top, with the clayey material previously excavated and this space was filled and graded to the top of the bank with loam.

On work of this kind it appears that one of the principal items of cost is in the plant, its installation and removal. While this might probably be expected, this item is, nevertheless, a larger proportion of the cost than one who was not familiar with such work might look for.

The cost of labor and materials can be closely estimated, but the cost of plant can only be judged accurately by those familiar with its use.

The following detailed statement of the cost of this work is given, not as record-breaking, but as the actual expense under ordinary conditions.

Two holidays intervened, and the men were transported to and from work. While it may be said that these items would not wholly appear in contract work, it may also be noted that the men employed were of a higher order of intelligence than ordinary labor, and that the increased cost from these items was perhaps balanced by more efficient work at less cost for supervision.

TABLE No. 1. — COST OF REPAIRS

Class	Rate	Excavation		Lower Concrete		Upper Concrete		Back Plaster	
		Days	Cost	Days	Cost	Days	Cost	Days	Cost
LABOR									
Foreman	$4 00	9 5/9	$38 22	3 7/9	$15 11	6 7/9	$27 11		
Sub-foreman	3 00								
Engineer	3 00	12 3/9	37 00	2 3/9	7 00	1 8/9	5 67		
Carpenter	2 67	2	5 33	7	18 67	18 5/9	49 48		
Plasterer	5 40							3 8/9	$21 00
Plasterer	6 00							8/9	5 33
Plasterer	4 50							5 5/9	25 00
Asphalt man	2 00								
Watchman	2 00								
Laborers	2 25	9 6/9	21 75	2 6/9	6 00	1 7/9	4 00	9 3/9	21 00
Laborers	2 00	110 2/9	220 44	89	178 00	119 5/9	239 11	3/9	67
Laborers	1 75	46 5/9	81 48	4	7 00				
D. Team	5 00								
S. Team	2 00								
S. Team	3 50								
Teaming									
Car fares									
Sum			$404 22		$231 78		$325 37		$73 00
PLANT	Rate								
Asphalt kettle	$1 50								
Derrick & engine	3 75	12 3/9	$46 25	2 3/9	$7 75	1 5/9	$6 33		
Rails and cars	0 40	11 2/9	4 49	2 2/9	89	8 3/9	3 33		
Sum			$50 74		$8 64		$9 66		
MATERIALS	Rate	Q'nt'y		Q'nt'y		Q'nt'y		Q'nt'y	
Cement, bbl.	$1 35			106 2/3	$143 61	176 1/2	$238 27	6	$8 10
Sand, cu. yd.	1 10			37 44	41 18	30 22	33 24	3 30	3 63
Stone dust, tons	1 50					41 61	62 42		
Br'k'n st'ne, ton	1 35			117 88	159 14	122 76	165 73		
Loam, cu. yd.	1 25								
Stove coal, tons	6 50	3 05	$19 83						
Egg coal, tons	6 25	95	6 00	40	2 50	20	1 25		
Lumber, M ft.	21 00			1 30	27 30	4 00	84 00		
Asphalt, tons	30 00								
Kerosene, gal.	0 11								
Oil, gal.	0 25								
Burlap, yds.	0 04 1/2					300	13 50		
Spikes, lbs.	0 05								
Nails, lbs.						170	4 50		
Asphalt mops									
Sum			$25 83		$373 73		$602 91		$11 73
Total			$480 79		$614 15		$937 94		$84 73
Estimated proportion, cost of plant installation & holidays		70 3%	$650 84	12%	$111 10	15 4%	$142 57		
Total cost			$1 131 63		$725 25		$1 080 51		$84 73
Total quantities			300 cu. yd.		95 5 cu. yd.		129 2 cu. yd.		262 sq. yd.
Cost per unit			$3 77		$7 59		$8 37		$0 32

TO LINING OF CHELSEA RESERVOIR.

Surfacing		Asphalt		Back Fill		Installing Plant		Transportation and Holidays		Summary Labor and Materials
Days	Cost	Days	Cost	Days	Cost	Days	Cost	D'ys	Cost	Cost
		$\frac{1}{9}$	$0 41	$1\frac{1}{3}$	$5 33	$15\frac{4}{9}$	$61 78	1	$4 00	$151 99
						1	3 00			3 00
						$8\frac{4}{9}$	25 33	1	3 00	78 00
						3	8 00	1	2 67	84 15
$7\frac{6}{9}$	$41 40									62 40
$2\frac{1}{3}$	12 67									18 00
$9\frac{1}{3}$	42 50									67 50
		11	22 00							22 00
						42	84 00			84 00
$12\frac{4}{9}$	28 00					$17\frac{4}{9}$	38 36	1	2 25	121 36
$2\frac{4}{9}$	4 89	6	12 00	$23\frac{1}{3}$	46 67	$149\frac{8}{9}$	299 78	23	46 00	1 047 56
				9	15 75					104 23
						$10\frac{1}{2}$	52 50			52 50
						6	12 00			12 00
						1	3 50			3 50
							53 00			53 00
									147 30	147 30
	$129 46		$34 11		$67 75		$641 25		$205 22	$2 112 49
		11	$16 50							$16 50
						$11\frac{4}{9}$	$42 92	1	$3 75	107 00
				$2\frac{2}{3}$	$1 07	$8\frac{2}{9}$	3 29	2	80	13 87
			$16 50		$1 07		$46 21		$4 55	$137 37
Q'nt'y		Q'nt'y		Q'nt'y		Q'nt'y				
$22\frac{1}{4}$	$30 04									$420 02
5 07	5 58									83 63
13 97	20 96									83 38
						7 05	$9 52			334 39
				$27\frac{5}{9}$	$34 45					34 45
										19 83
						0 6	3 75			13 50
										111 30
		3.9	$117 00							117 00
						30	3 30			3 30
						4	1 00			1 00
										13 50
						220	11 00			11 00
										4 50
			3 00							3 00
	$56 58		$120 00		$34 45		$28 57			$1 253 80
	$186 04		$170 94		$103 27		$716 03		$209 77	$3 503 66
				2.3%	21 29					
	$186 04 460 sq. yd.		$170 94 464 sq. yd.		$124 56 75 cu. yd.					$3 503 66
	$0 40		$0 37		$1 66					

TABLE No. 2.

REPAIRING LINING OF CHELSEA RESERVOIR. — UNIT COSTS (per cu. yd.).

Concrete, lower layer — Mixture 1–$2\frac{1}{2}$–$6\frac{1}{2}$.
95.5 cu. yds.

Atlas cement,	1.11 bbl. @ $1.35,		$1.50
Sand,	0.39 cu. yd. @ $1.10,		.43
Broken stone,	1.23 tons @ $1.35,		1.66
Lumber for forms,	.014 M ft. @ $21.00,		.29
Miscellaneous expenses, plant, coal, etc.,			1.28
Labor:			
Mixing and placing,		$2.09	
Carpenter work on forms,		.34	2.43
Cost per cubic yard in place,			$7.59

Cement:
1 bbl. cement per 0.89 cu. yd. concrete.
1 cu. yd. concrete per 1.11 bbl. cement.

Sand:
1 cu. yd. sand per 2.55 cu. yds. concrete.
1 load (40 cu. ft.) per 3.77 cu. yds. concrete.
1 cu. yd. concrete per 0.39 cu. yd. sand.
1 cu. yd. concrete per 0.26 load sand.

Broken stone:
1 ton stone per 0.81 cu. yd. concrete.
1 cu yd. stone per 1.03 cu. yds. concrete.
1 cu. yd. concrete per 0.97 cu. yd. stone.
1 cu. yd. concrete per 1.23 tons stone.

1 cu. ft. dust weighs 103 lbs.
1 cu. ft. stone ($\frac{3}{4}''$ to $1\frac{1}{2}''$) weighs 94 lbs.
1 cu. yd. dust weighs 1.39 tons.
1 cu. yd. stone weighs 1.269 tons.
1 ton stone occupies 0.788 cu. yd.
1 ton dust occupies 0.720 cu. yd.

Concrete, upper layer — 1 : $1\frac{1}{4}$: $1\frac{1}{4}$: 4.
129.2 cu. yds.

Atlas cement,	1.37 bbl. @ $1.35,		$1.85
Sand,	.24 cu. yd. @ $1.10,		.26
Dust,	.32 ton @ $1.50,		.48
Broken stone,	.96 ton @ $1.35,		1.30
Lumber,	.031$\frac{1}{4}$M ft. @ $21.00,		.65
Miscellaneous expenses, plant, etc.,			1.32
Labor:			
Mixing and placing,		$1.85	
Carpenter work on forms,		.66	2.51
			$8.37

Cement:

1 bbl. cement per 0.74 cu. yd. concrete.
1 cu. yd. concrete per 1.37 bbl. cement.

Sand:

1 cu. yd. sand per 4.28 cu. yds. concrete.
1 load sand (40 cu. ft.) per 6.34 cu. yds. concrete.
1 cu. yd. concrete per 0.23 cu. yd. sand.
1 cu. yd. concrete per 0.16 load sand.

Dust:

1 ton dust per 3.10 cu. yds. concrete.
1 cu. yd. dust per 3.94 cu. yds. concrete.
1 cu. yd. concrete per 0.25 cu. yd. dust.
1 cu. yd. concrete per 0.32 ton dust.

Stone:

1 ton stone per 1.05 cu. yds. concrete.
1 cu. yd. stone per 1.34 cu. yds. concrete.
1 cu. yd. concrete per 0.75 cu. yd. stone.
1 cu. yd. concrete per 0.95 ton stone.

Voids in stone:

Oil barrel filled with stone. Weight of barrel deducted.

Barrel of stone, 742 lbs.
Barrel of water, 510 lbs.
Barrel of stone and water, 942 lbs.

Per cent. voids, $\frac{942 - 742}{510} = 0.39.$

The following approximate *labor* costs are given:

Transporting, erecting, and removing derrick	$260.85
Equivalent time — foreman, 6 days; engineer, 4 days; laborer, 85 days.	
Transporting, laying, and removing track	125.03
Equivalent time — foreman, 4 days; laborer, 40 days.	
Caring for dump and disposing of surplus by rough grading	70.28
Equivalent time — foreman, 1 day; laborer, 33 days.	

As stated above, the work was planned and carried out under the general supervision of the Engineering Department of the Metropolitan Water Works, of which Mr. Frederic P. Stearns is chief engineer, and Mr. Dexter Brackett engineer of the Distribution and Sudbury departments.

SUPERHEATED STEAM IN PUMPING ENGINES.

BY E. H. FOSTER, M. E., NEW YORK CITY.

[*Read September 15, 1904.*]

Much has recently been said and done about superheating steam as a preparation for its more efficient utilization in driving various forms of steam engines.

As has been frequently remarked, this feature of modern engineering is rather the result of reviving an old art than the introduction of a new principle. Engineers of two or three generations ago were fully aware of the advantages to be derived by superheating steam, but in their efforts to obtain these advantages in practice they encountered certain obstacles which have since been attributed to the primitively crude condition of the steam engine and to the lack of such proper facilities as are in common use to-day, such as mineral oil for lubrication, improved stuffing-box packing and steam-pipe gaskets.

A most natural question would be: If superheating has been found so useful, why is it that we only now approach the subject very much as if it were a novelty? We have indulged in the foregoing remarks for the purpose of providing an answer to this question.

The scantiness of opportunities for installing superheaters naturally hindered designers and builders from bringing the apparatus to a high state of development. It is only by repeated execution that even the most obvious improvements may be devised, and it may be said that in this country at least the superheater was waiting on the steam engine and the steam engine was waiting on the superheater, without their being used together until the advent of the steam turbine as a commercial machine, which certainly must be recognized as presenting a great opportunity for the development of the superheater.

With the steam turbine there seems to be no doubt that it is highly important to have the steam superheated, and provision

has been made for this in all the important plants which have been and are now being installed. This competition has naturally spurred our engine builders to the point of asking why their engines are not as suited to superheated steam as is the steam turbine.

In looking about for experience it has been found necessary to go to Europe for the greatest number of practical examples. The inducement of more expensive fuel has probably had much to do with European progress in this direction.

While it has not been found possible to transplant to this country European practice *in toto*, we have undoubtedly been considerably aided by studying these methods. It was in the study of this question in Europe that our attention was first called to the adaptability of the superheater to water-works engines, and this is the point which we wish to emphasize more particularly in this paper.

No form of steam plant could be better adapted to the use of superheated steam, and in no more simple way can pumping-engine duties be surely improved.

An interesting work on water supply published by the Indian government is the "Roorkee Treatise on Civil Engineering," Vol. II, Section xii, 1902 edition. M. D. W. Aikman, the author, remarks in describing superheaters:

"The advantage of superheating steam before utilizing it in the engine is to increase the efficiency of the engine from 8 to 12 per cent. Superheating is effected by conveying the steam from the boiler or steam drum through the furnace before sending it on to the engine. The cast-iron pipe conveying the steam through the furnace is made U-shaped, so as to give the steam a long distance to travel in the furnace. This pipe has circular lugs cast round it (close together) outside, and longitudinal lugs inside, so that the radiation of heat from the furnace to the steam may be as much as possible. By superheating steam its volume is increased whilst its pressure remains unchanged. Also the many particles of water carried from the spray of the boilers are converted into steam. If these particles of water are not converted into steam, they not only do no useful work, but they cause considerable annoyance in the working of a steam engine by what is technically called 'priming.'"

These words are amply corroborated by a number of tests

which have been made on various forms of pumping engines, among which may be mentioned the triple-expansion Sulzer engine at St. Galles, Switzerland, the triple-expansion Worthington engines at London and St. Albans, and the vertical triple-expansion crank and fly-wheel engine at Grand Junction Water Works, England, and the twenty Worthington horizontal triple-expansion high-duty pumping engines on the great Coolgardie pipe line, Western Australia. Sufficient data have already been obtained in this country to corroborate the figures obtained in Europe, and tests have been made at the water works at Norfolk, Va., Brooklyn, N. Y., at two main pumping stations in Chicago, Ill., and at the two high-service stations in New York, on engines of various sizes and conditions of service. In all cases it appears that superheated steam was attended not only by the desired steam and fuel economy, but by most satisfactory results in the handling and operation of the machines.

Further data will be forthcoming before very long, as the Allis-Chalmers Company are installing superheaters in connection with the three 25 000 000 gallon vertical triples they are erecting at the North Side Station in Chicago. R. D. Wood & Co. are also putting in two separately fired superheaters to serve the four 30 000 000 gallon triple-expansion crank and fly-wheel engines which they are installing at the new low-service pumping station in Cincinnati. When this paper was undertaken, it was hoped that some of the figures which would naturally be forthcoming from the tests of these plants would be available by this time.

Data with reference to such tests as have been made in this country may readily be obtained by those interested.

A most elaborate test was made on each of the six 20 000 000 gallon vertical triples at Chicago by a board of experts, and the results published in *Engineering News*, May 6 of this year.

Although there is considerable variation in the duties given by different engines of the same size, it has been established that the remarkable showing made by these engines is due entirely to superheated steam, and that the amount of superheat bears directly on the duty.

The writer contributed to the American Society of Mechanical Engineers in 1899 some figures obtained in a series of very care-

ful tests of a low-duty triple-expansion Worthington engine of 100 horse-power on intermittent service.

Last winter a series of tests was run at the New York City water works, and made the object of a thesis by Messrs. H. S. Brown and J. F. Muller, students at Cornell University. These tests were very carefully supervised by Professor Carpenter, and some very interesting results were obtained.

We extract the following:

Conditions.		Duty per 1 000 lbs. steam.
Saturated steam	All cylinders jacketed	138 mill.
Steam superheated 47.3 degrees.	All cylinders jacketed	151 mill.
Steam superheated 80 degrees	L. P. cylinders only jacketed	155 mill.

But possibly the most interesting and practical of all tests is one made by the city of Brooklyn during the early part of this year in connection with the pumping station at Spring Creek, which is one of the points where ground water is delivered into the conduit. This station is an old one, having been in use for ten or twelve years, and is equipped with two Knowles compound, condensing, direct-acting duplex pumps, size $6\frac{1}{2}$ and $11\frac{1}{2} \times 16 \times 24$, and one Davidson triple direct-acting condensing pump, size 18 and $24 \times 24 \times 24$ inches. Each pump is equipped with an independent jet condenser, the exhaust steam of which is used to heat the feed water. The boilers are of the horizontal return tubular type, 60 inches in diameter by 15 feet long, with 76 3-inch tubes or 915 square feet of heating surface and 25 square feet of grate surface. White-ash anthracite coal in large size is burned with natural draught.

This test was made by equipping one boiler with a superheater and running a series of alternate tests with each boiler independently. It was desired to know just how much fuel could be saved in a station of this character under its regular working conditions. The results were most satisfactory.

The first tests were made by the contractors with the city engineer, of twenty-four hours each, both with saturated and

superheated steam. The results were a saving in coal per foot-pound of work done of 20.2 per cent., and saving in feed water of 23.2 per cent. The average temperature of steam on leaving the superheater was 527°, corresponding to a superheat of 207°, since the steam pressure was only 80 pounds per square inch.

These tests were most conclusive, but the supervising engineer thought to convince himself still further as to the value of the device and made a five-day test under average working conditions with superheated steam, following this by a five-day test under similar conditions with saturated steam. He reported a saving somewhat in excess of those obtained on the official test.

The plant offered such inducements for scientific investigation that three students from the Stevens Institute selected this as a subject for their joint thesis, and a series of tests were made under the direction of Professor Jacobus and Professor Pryor. The results obtained on these tests showed a remarkable saving, due to the introduction of superheated steam, as follows:

	Saturated Steam.	Superheated Steam.	Increase Per Cent.
Duty per 100 lbs. coal as fired	19 888 784	24 532 704	17.4
Duty per 1 000 000 B. T. U.'s supplied to pumps	23 503 690	27 864 280	18.5
Total ft. lbs. of work per pound of coal as fired	421 344	508 808	18.1
Total ft. lbs. of work per pound of combustible	519 984	640 944	23.0

There seems to be no doubt about the perfect demonstration of the great value of this device in this instance, and it is of especial interest to know that no change whatever in the character of the oil or packing, or steam pipe gaskets, or any other features of the plant were made; but it was kept in the same condition as it had been running for several years.

A recent inquiry as to the conditions at the station reveals the fact that the good results are continuing. It also develops that when cleaning the superheating boiler it is necessary to run the plant with saturated steam, but that the steam is changed from saturated to superheated, and vice versa, with impunity, and no

objectionable results. It is planned by the chief engineer to attach a superheater to the other boiler at this station as soon as possible.

The advantages of superheating may be classified under three heads:

First. A reduction in initial cost of the plant if designed for superheated steam, or an enlargement of the power of an existing plant.

This reduction consists in the employment of a more simple form of steam engine to do a given amount of work and give a specified duty, and the simplification is in the omission of such devices as are rendered superfluous by the use of superheated steam, such as steam jackets and separators. Another example of the simplification thus rendered possible would be the use of a compound engine in place of a triple or of a simple in place of a compound, the superheater supplying the economy which is otherwise effected by multiplicity of cylinders.

The increase in power by introducing superheat is chiefly recognized in the greater capacity given the boilers; for instance, it is frequently found in practice that by the introduction of superheaters in a plant requiring four or five boilers to operate, at least one of these units is put in reserve; thus in considering the extension of boiler capacity, there will always be the alternative of installing superheaters.

Superheating also materially affects the question of steam-pipe sizes. For many unfounded reasons it has been the custom in this country to gradually increase the size of steam pipes, until in some instances they are of really ridiculous proportions. The development should have been in the other direction. As steam pressures and revolutions per minute are increased, it is unnecessary to use such large pipes, and many peculiarities of our steam indicator diagrams which have been laid to too small a steam pipe have been proved to arise from other causes. Tendency to higher velocities in steam mains, which means the use of smaller pipes, is undoubtedly very marked, and this tendency is considerably aided by superheating, as a lighter gas will travel in the main with higher velocity without the same loss of pressure due to friction.

Second. The increase of engine duty due to the elimination of cylinder condensation and the greater efficiency of the steam when superheated. As a result of comparing efficiency tests and the conditions under which they were made, we have prepared a brief table of the saving which might reasonably be expected from the use of superheated steam in various types of engines as distinguished by the duties which they perform in foot pounds per million heat units.

Duty of Pumping Engine.	Saving by 100° Superheat.
150 000 000	6%
100 000 000	10%
50 000 000	20%
10 000 000	40%

Third. The general improvement in the conditions of starting and operating the engine. This is a point which cannot be so easily measured in dollars and cents, but one which is of great importance nevertheless.

With superheated steam in the engine it responds more quickly to the action of the governor and cut-offs; it is a machine which is more easily controlled because of the lack of water in the cylinders and steam pipes; it is easier to keep clean externally, while the internal parts are well preserved, and piston lubrication is rendered more efficient owing to the lack of water in the cylinders.

We want superheated steam on this account just as we want our engine rooms and our attendants kept neat and clean, and just as we want a fine brick or stone building for an engine house and well-kept grounds, instead of a ramshackle wooden shanty surrounded by rough grounds, such, for instance, as would be found at an oil-well pumping station.

We heard an erecting man of one of our largest engine-building concerns recently commenting on his first experience in starting up an engine with superheated steam. He said that he had never had so little trouble with a new engine, and whatever the advantages of fuel consumption might be, he was convinced that superheated steam was good for the engine from the operator's point of view.

Pumping engines which are called upon to assume suddenly increased loads are greatly benefited by superheating the steam.

as they are thus enabled to respond more quickly and more fully to the demand for extra work.

The same effect from superheating has been observed in electric power stations when a peak occurs in the load, and more particularly in locomotives, where careful tests have demonstrated that those equipped with superheaters lose much less time in getting under way from stations, and take the excessive grades more easily.

The means for obtaining superheated steam must depend largely upon the conditions at hand.

An ideal arrangement would be to have a separately fired superheater in which the superheat can be regulated carefully to suit the requirements of the conditions. (Fig. 1.)

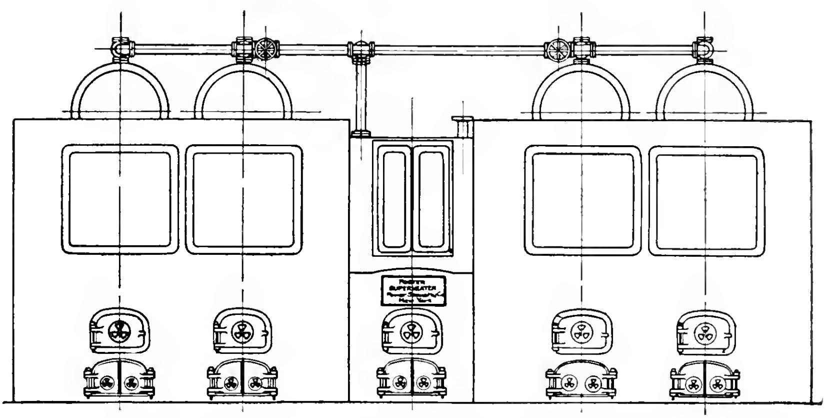


Fig. 1. Arrangement of Foster Superheater with Separate Furnace, Set between Two Batteries of Boilers, Showing Minimum Surface Exposed for Radiation and Direct Pipe Connections.

The principal objections to the separately fired arrangement are the possible complication in steam piping, or the loss of heat due to radiation. As to the former, it may be said that the objections are really very slight, as it has been found that with a little care a simple and efficient system of piping may be worked out, which will answer all the requirements as to safety and convenience, whereas the external radiation from the superheater setting is overcome by placing the superheater between or close

up to the setting of the boilers. A very good arrangement for a separately fired apparatus is to assume, for instance, a battery of four boilers, one of which is in reserve, and install a superheater large enough to superheat the steam from three of the boilers, and place the superheater in between the two batteries. This arrangement makes very simple piping and utilizes the space to the best advantage. It is possible to arrange a superheater in this location without interfering with the openings for blowing

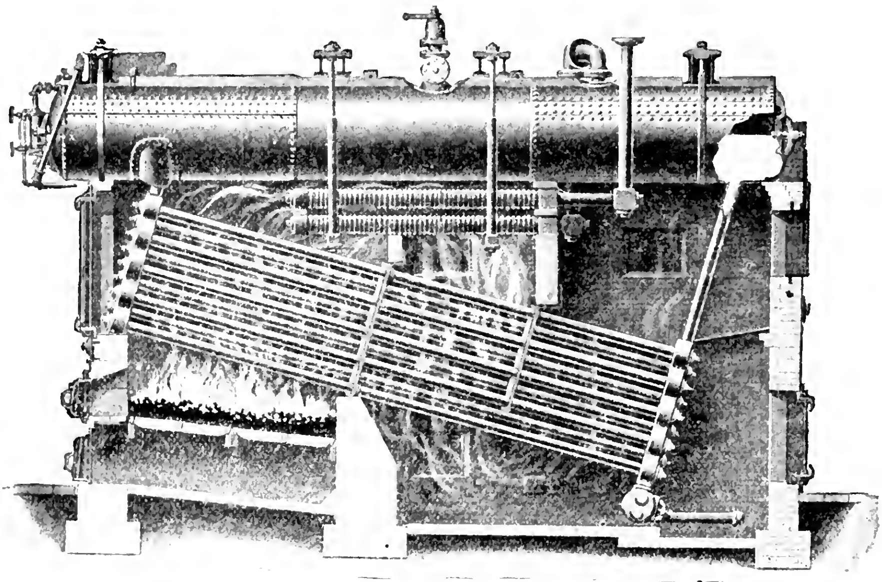


FIG. 2. FOSTER SUPERHEATER COMBINED WITH B. & W. BOILER.

the boiler tubes. The convenience of placing superheaters in such a position as to utilize part of the heat of the boiler gases has led to the development of what may now be considered as well-known standard arrangements, which are illustrated by the accompanying figures.

For instance, for a horizontal water tubular boiler with inclined water tubes and a horizontal drum, Fig. 2, a most convenient point for locating the superheater has been found just under the drum and above the tubes, the steam being drawn from the dry

pipe in the usual manner and passed through pipes into the superheater, and carried out at a point near the original boiler outlet.

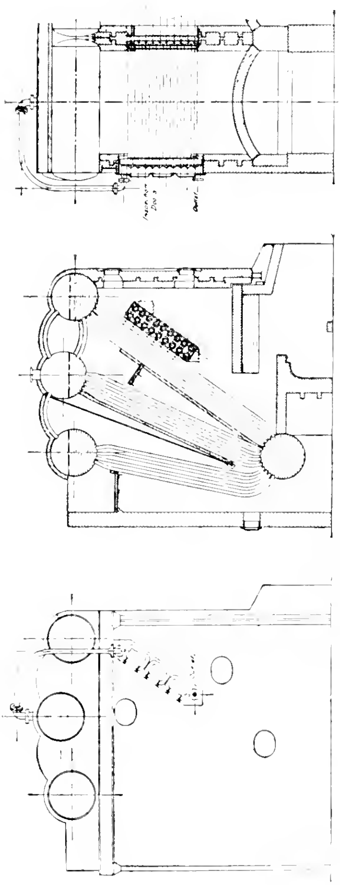


FIG. 3. FOSTER SUPERHEATER COMBINED WITH STIRLING BOILER.

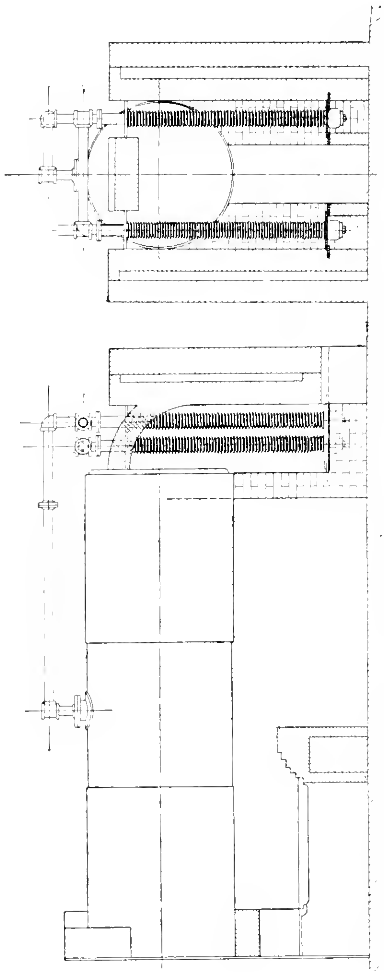


FIG. 4. FOSTER SUPERHEATER COMBINED WITH HORIZONTAL RETURN TUBULAR BOILER.

In horizontal water tubular boilers with inclined drums there is not sufficient space between the drums and the tubes for the location of a superheater, and it has been found necessary to

leave out one or two horizontal rows of tubes about the middle of the boiler to provide a space for the superheater.

In the vertical bent tube boiler, Fig. 3, a space for the superheater is found immediately over the furnace arch, while in horizontal return tubular boilers, Fig. 4, and the internally fired marine type of boiler, Fig. 5, an ideal place for the superheater exists in the rear combustion chamber.

To insure long life and efficiency of operation a superheater should present a cast-iron surface to the action of the furnace gases. The most successful types in European practice have been made wholly of cast iron, but this method of construction

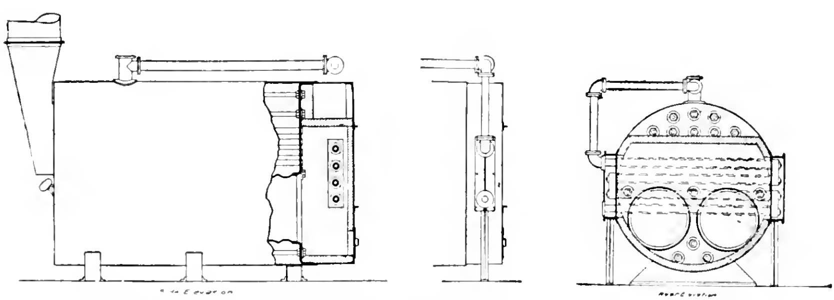


FIG. 5. FOSTER SUPERHEATER COMBINED WITH INTERNALLY FIRED TUBULAR BOILER.

is considered somewhat objectionable, particularly in this country, where cast iron has been proved a treacherous material for boilers and steam pipes.

To utilize the good features of cast iron as a resister of the corrosive effects of the furnace gases, and at the same time obtain the advantages of the wrought-steel construction, superheaters have been constructed largely by using a solid drawn-steel tube such as a Shelby tube, for a body, on the outside of which are shrunk a series of deep annular gills, closely set together so as to completely cover the external surface of the tube and protect the same from blistering or corrosion, as shown in Fig. 6. This results in a form of tube with deep external corrugations, giving an extended surface for the absorption of heat, and giving greatly increased strength to resist bursting strains. The in-

ternal surface of the Shelby tube being particularly smooth, steam may be passed through it at a very high velocity without undue friction losses, and in the form of superheater now being described this velocity is insured by annular distribution, consisting of internal filling tubes placed within the main tube

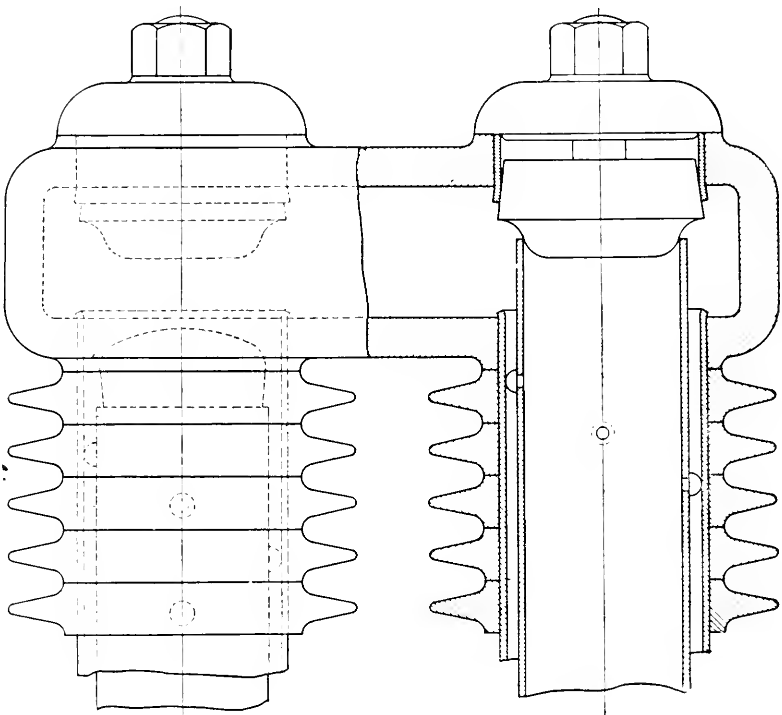


FIG. 6. DETAIL OF FOSTER SUPERHEATER SHOWING CONSTRUCTION OF ELEMENTS AND HEATERS.

and held centrally so as to provide annular spaces for the passage of the steam.

The tubes are joined at their ends by expanding them into wrought or cast-steel headers and return boxes, and are arranged so as to give flexibility.

This form of construction has been successfully applied to

several thousand horse-power of boilers and has been utilized in a number of independently fired superheaters, and is apparently meeting the requirements of durability and efficiency.

That the superheater is already well beyond the experimental state needs no greater proof than a recent report of the United States consul in Germany, to the effect that its use is now general in connection with engines in that country, and a statement by the largest manufacturers of water tube boilers in Great Britain that of all the boilers which they turned out last year over eighty per cent. were fitted with superheaters.

There is no reason why each and every water-works engineer who is not using superheated steam should not take immediate advantage of this simple and comparatively inexpensive method of increasing his engine duty.

Mr. F. W. Dean brought up this point before the Association last winter as a very promising and practically the *only* remaining method in sight of raising duties.

We do not know of any improvement which would require less attention, nor do we know of any which would be more sure of giving a good account. What more appropriate place for its rapid introduction than New England, the home of high-class pumping engines and of low pumping costs?

DISCUSSION.

Mr. J. Herbert Shedd. I have had very little experience with superheated steam for pumping water. The first and almost the only experience I had was about thirty years ago in undertaking to run superheated steam through a Worthington horizontal low-duty engine, with the result that we set the wooden lagging on fire. We didn't pursue the experiment.

The President. It would really seem as though the ordinary duplex engine was one of the machines which was best suited for the use of superheated steam. Certainly if its duty can be increased thirty or forty per cent., as mentioned in the paper, a very promising field is opened.

Mr. Edward Atkinson. Mr. President, the danger of fire is not confined to the danger from superheated steam. The heavi-

est loss that the factory mutual companies ever suffered came from the most unexpected cause, and that was the sudden bursting into flame, almost an explosion, of the wooden lagging of a 10-inch cylinder of a compound engine, as the result of which the three Warren Mills were totally destroyed, with the contract made, the pipes on the ground, but the sprinklers that would have stopped the fire where it originated not put up. Beware of wooden lagging on any boiler or cylinder anywhere, superheated or low-heated, or otherwise.

Mr. W. C. Hawley. Mr. Foster mentions the possible saving with engines running at various duties. I would like to ask at what steam pressure he would start in making those savings, and whether such a saving would be a possibility with an initial pressure of 175 or 200 pounds, which is sometimes carried in large pumps.

Mr. Foster. I will say, without having elaborated that point very much in the paper, that the idea would be to expect those duties with the steam pressures for which the engines were designed. For instance, an engine of 150 000 000 duty would naturally have a high steam pressure, say of 150 pounds, and an engine of 40 000 000 duty would not usually carry more than from 100 to 125 pounds. It is expected that those pressures would automatically take care of themselves in considering the question generally.

The President. The idea being that low-duty engines are very much more benefited by superheating the steam than the high-duty engines, and in the case of a direct-acting pumping engine, such as the duplex engine, the duty could be increased enormously without the introduction of new boilers by superheating the steam. That is the idea, isn't it, Mr. Foster?

Mr. Foster. Yes, sir; that is the idea.

THE ADVANTAGE OF A SCIENTIFIC BASIS FOR DETERMINING THE VALUE OF FUELS.

BY HENRY J. WILLIAMS, CHEMICAL ENGINEER, BOSTON, MASS.

[*Read December 12, 1904.*]

The question of testing coals by analysis and calorimeter test, to determine their value, as well as by boiler test, is an important one, which is of interest to-day to the engineer and to the large purchaser of coal quite as much as it is to the chemist, for the realization is slowly coming home to us that coal cannot be economically used for making steam unless we know accurately its quality or intrinsic value in addition to knowing simply its name and its cost per ton.

Too many false notions about coal which lead to erroneous conclusions are unfortunately held at the present time, much of the confusion doubtless arising from the fact that the knowledge which we possess about the different coals, or one particular coal as it is shipped from different mines, is incomplete or inexact, and is not at all conclusive in consequence. The question is often asked, "But how are we to reliably know what we are getting?" Science, and science only, can answer that question. Science is, after all, but systematized knowledge, with all errors, wherever possible, detected and discarded. We are far more likely, therefore, to know what we are about, in purchasing coal, if we are guided by the facts which we know to be true, rather than if we permit ourselves to be influenced by opinions which are unsound and facts which are incomplete.

A discussion of certain aspects of this problem, from the point of view of one who has conscientiously labored for many years in attempts to discover what is unsound and remedy much that is untrue, may prove of interest, and it may serve to suggest a practical way out of our difficulties.

The values which we actually realize from coal, in the form of steam or work, depend first upon the nature, composition, and

fuel value of the coal, which are best determined by the chemist who makes a specialty of such work, and second, upon its behavior during combustion, which the engineer controls. But the process of combustion is as intimately connected with chemistry as it is with physics, so that an exact knowledge of the manner in which combustion proceeds is only to be gained when the engineer and the chemist work together. Such troubles, for instance, as excessive or insufficient draught, imperfect combustion, leakages of air above or through the fire, improper sizing of the coal, excessive thickness of fire, improper grate area for the amount of steam produced, too slow combustion, etc., are all readily detected by a correct interpretation of the results of accurate flue gas analyses, and the proper remedy then suggests itself. Such information, promptly utilized, serves to reveal and at once remedy the disadvantageous conditions of burning which would otherwise continue undetected, and many times even unsuspected.

The boiler test, taken by itself, on the one hand, tells us but little about the intrinsic value of a fuel, for it is subject to many inevitable losses of heat which occur from various causes and which vary widely with different furnaces. By slightly varying the conditions we can obtain, at will, in the same furnace, either a good or a bad result, with precisely the same coal, so that the final results, at best, may be quite deceptive, and nothing definite about the true value of the coal, as a fuel, is really learned.

The analysis and calorimeter test, on the other hand, while they do not tell us how to handle or burn the coal, unquestionably serve to fix *definite* and *invariable standards* to go by, towards which we may strive. When properly made they tell us accurately and positively with just what kind of coal we are dealing, the exact number of heat units which its complete combustion will yield, the percentages of moisture, volatile matter, fixed carbon, ash, and sulphur which the coal contains, and the influence of the latter upon the heating power. If carried far enough they reveal also the ultimate composition of the coal, the nature of the ash, its fusibility and other properties. With this information we are enabled to select a suitable fuel for almost any kind of work with adequate knowledge of what we are about, but it is the height of folly to rashly conclude that all chemical analyses

are of no value simply because an incomplete analysis of a coal fails to tell more than it is capable of revealing, and yet this is what is frequently done.

A poor coal, of low heating power, is sometimes said, with some degree of truth, to yield higher results under a certain boiler than a better coal, of the same nature but of greater heating power, and the erroneous conclusion is confidently reached *that the better coal is of inferior quality.* This surprising though all too frequent conclusion is solely due to the fact that some important factor has not been taken into account, and it affords another instance of the folly of drawing conclusions from insufficient premises. The heat value of a unit of carbon or of hydrogen is practically the same in all coals of the same nature, but the better coal may have been lump coal, which left spaces beween the lumps when placed upon the grate, while the poorer fuel consisted of fine screenings which packed closely and left no such spaces. In consequence, a leakage of air occurred between the lumps of larger coal, which cooled the fire and reduced its efficiency. Stopping this leakage of air, which occurred in the one case and not in the other, would have been all that was required to actually realize and apply the greater heating power of the better coal. The conclusion formerly reached would then have been reversed.

The above illustrations seem plainly to indicate that the results of boiler tests, unaccompanied by chemical analyses, are deceptive, because the conditions under which they are made are largely unknown quantities, or can, at best, only be surmised. When these tests are accompanied by reliable analyses and calorimeter tests of the coal and properly interpreted analyses of the flue gases, the conditions under which they are conducted cease to be unknown quantities and their results become definite, convincing and conclusive.

It is sometimes the custom for the engineer to make the flue gas analyses himself, and occasionally the analysis and calorimeter test of the coal also. As a general rule this practice is not to be recommended, for, while the results which he obtains may sometimes be better than no results at all, the conclusions are quite likely to be faulty or deceptive, owing to his insufficient experience or necessarily limited knowledge of chemistry. This

work is entirely out of his line and he is generally too busy about other matters during a boiler test to do it properly.

The results of reliable analyses and calorimeter tests of coal, which are definite quantities, seem also to furnish all the information that is required to enable us to purchase coal intelligently and on a definite basis. But it is of vital importance, if we are to be guided by the results of such tests, that their accuracy should be beyond question, and it is an unfortunate fact to record that, owing to the woefully incomplete knowledge about coal which is generally possessed and to defective calorimeters, much of the work which is being done to-day, in this line, is none too good.

Conscious of the many shortcomings on this side of the question, the writer has left no stone unturned in efforts to overcome them.

Investigations have now been carried on for nearly ten years to improve our methods of conducting analyses and calorimeter tests and to accumulate reliable data about all kinds of coal which should reveal what is true and what is false. Briefly outlined, this work has included:

1. Complete proximate and ultimate analyses of more than three hundred different American coals, together with calculations of their theoretical heating powers.

2. An exhaustive investigation, lasting two years and a half, to discover reliable methods for determining moisture in coal, including more than two thousand separate determinations.

3. A study of modern calorimeters and of the errors to which they are liable.

4. The production of a perfected form of bomb calorimeter that should be free from all such errors and as accurate and convenient to operate as mechanical skill could make it.

5. Accurate calorimeter tests of all of the above coals.

Many other kindred subjects have been investigated, and numerous machines, forms of apparatus and methods of examination have been devised, constructed, and made use of, to make it possible to bring the investigation to a successful issue. A slight outline of the scope of this work is all that can here be given, but it is now practically completed and the writer expects to publish it in full, in book form, at the earliest opportunity.

Sufficient reliable data seem to have been collected, however, to bring the difficult question of "coal," which here confronts us, under fair control.

Coal, as it occurs in the seam, is seldom free from partings of slate, "bone," or inferior coal, which it is the duty of the miner to sort out; but, for one reason or another, this is seldom perfectly done, particularly where the seam becomes thin, and, as a natural consequence, a great many different grades of genuine coal of the same name, but from different mines or places, find their way to market. That this is the case, the following facts, taken from the writer's experience, seem conclusively to show:

A certain coal, in common use, whose name is omitted for obvious reasons, generally carries on an average 6.58 per cent. ash, this result being the average of more than twenty analyses of this coal, as it occurs in the market, made by the author in connection with boiler tests. He has also analyzed fair samples of this coal showing 8 per cent., 10 per cent., 14 per cent., and recently over 22 per cent. of ash. Is it possible, in the face of such evidence, to still believe that *the name* of this coal is any guarantee of its quality?

What is true of this coal it true of many others. The one cry of suffering consumers is: "Give us coal of *uniform* quality," but do they get it, at any price?

The writer some years ago had occasion to analyze a great many samples of turpentine, as it occurs in the market in some sections of this country. The results were most interesting. Carefully interpreted they seemed to suggest that the manner of selling turpentine is based on the fact that turpentine is worth 45 cents per gallon and naphtha 10 cents.

The drummer is told to "get orders, — at *any* price," and brings in quite a variety. The goods are then sent out as follows:

The man who pays 45 cents per gallon gets — straight turpentine (if he is lucky).

The man who pays 41½ cents per gallon gets — 90 per cent. of turpentine and 10 per cent. of naphtha, nicely blended.

The man who pays 39¾ cents per gallon gets — 85 per cent. of turpentine and 15 per cent. of naphtha, also nicely blended.

The dealer is contented because his profit is *just the same on*

all orders, and the customer is happy because he has bought his turpentine *below market price*. But has he?

Returning to the subject of coal, is it reasonable to suppose that, where there is a Yankee at both ends of the bargain, the customer who is unwilling to pay what good coal, or anything else, is worth, gets any better coal, or anything else, than he pays for? We think not.

Unfortunately this admirable adjustment does not always take place, and the sinners are not the only ones that suffer from poor coal of irregular quality.

Verily the world doth move. Does it not, therefore, seem reasonable to suggest that a system of purchase, based upon the *quality* and *heating power* of the coal, which are fixed quantities determined by analysis and calorimeter test, that would insure to the consumer a *uniform quality* of coal, for a *definite* price, and to the coal dealer *proper return* for his poorest as well as his best grades of coal, would be fair and equitable to *both* and would have many advantages to recommend it?

Such a system seems to the writer to be the only fair and logical way of dealing with this perplexing question, and it is a fact that wherever it has been properly tried it has given satisfaction, while in some places the bills have even been cut in two.

It is essential in all tests of coal that the sample operated upon should fairly represent the whole of the coal under investigation, otherwise the best work of the chemist is of no avail and the results are misleading. To do this successfully, however, requires skill, judgment, and experience and a faithful adherence to certain fundamental principles of correct sampling which are too seldom observed. It is almost needless to point out that to pick out a few small lumps, here and there, and to put in a few pieces of "bone," even if judgment (?) is used, is radically wrong and violates a vital principle of all correct sampling.

Owing to the various conditions under which coal is found, sometimes in lump form, sometimes fine, sometimes a mixture of the two, with more or less slate interspersed, sometimes in the yard, sometimes in the bins, sometimes on the cars or in the barge, it would be hopeless, in a brief paper, to attempt to lay down hard and fast rules which would apply to all cases. A few sug-

gestions only can be offered in illustration of the fundamental principles which govern all sampling, which should ever be kept in mind. These are:

1. To completely eliminate the personal factor of choice or selection.

2. To secure sufficiently large individual samples of uniform size, including lump, fine, bone, etc., from a sufficient number of different places, equidistant from each other, and representing all parts of the pile. This yields a reasonably fair average of the whole pile.

3. To unite and crush all the coal taken out to a uniform size, particularly the hard lumps of slate, mix with the utmost thoroughness on a clean floor, make into a pile, flatten this down and quarter evenly, throwing out two diagonal quarters perfectly clean, then repeat the above process, pulverizing finer and finer, until a sample of twenty-five pounds or less remains, the whole of which should be preserved for analysis.

The application of these rules, under varying conditions, calls for much ingenuity and skill, which can only be gained by experience, but a fair sample of the coal can almost invariably be secured in this manner, the reliability of which can readily be confirmed, in very important cases, by repeating the sampling from an equal number of different places.

The writer recently had occasion to sample in duplicate some 15 000 tons of New River coal, lying in the yard in a pile 12 feet broad, 20 feet thick and 150 feet long. The top of the pile and one exposed end were the only points accessible. This coal had been sold for "New River coal," but the mill manager claimed that it was not, that it gave bad results, etc., and refused payment except at an unwarrantable discount.

A brief description of how the sampling was done will illustrate the manner in which the above rules were complied with.

Starting on top, at the rear, ten stakes were put in, to mark ten spots fifteen feet apart; then, to eliminate the personal factor of choice, the surface coal was shoveled out level at each spot to a depth of four to six inches. With a pick the coal was uniformly broken up at each spot to an additional depth of about four inches over an area three feet square, and after very

thorough mixing of the loosened coal three large shovelfuls were taken from each hole. A half shovelful or less of surface coal was also taken between each of the ten holes. Then, proceeding to the face of the pile, the outer coal was removed and three shovelfuls were taken from each of four spots five feet apart, situated at different levels.

The whole of this coal, representing about six hundred pounds, was then dumped upon a clean floor, all the lumps broken, thorough mixture effected, and the quartering down process applied. Two samples, taken one after the other, from different sets of holes, in the above manner, yielded by analysis:

Sample No. 1.	Sample No. 2.
Ash..........6.07 per cent.	Ash........6.15 per cent.

The difference is only .08 per cent., so that either sampling can be considered reliable. Other confirmatory results were obtained, and the writer was able to state, with good grounds for his belief, that the coal in question was "New River coal," and that the complaint which had been made had no foundation in fact. Settlement in full for the coal was made within three weeks, so that further comments seem unnecessary.

Where sampling has to be frequently performed a small jaw crusher, of the Blake type, is very desirable, as it greatly hastens and simplifies the work and makes it more reliable. Various devices are also in use to avoid the necessity for the laborious and somewhat unreliable quartering. When samples are reduced to three eighths of an inch and finer, an improved form of the well-known tin sampler, which the author has perfected, reduces the labor of handling to a minimum, avoids all errors due to imperfect mixing and greatly increases the reliability of the samples. The ordinary sampler consists of a stiff metal frame provided with narrow longitudinal troughs, set parallel, between which there are open spaces of the same width, through which the material can fall. When the sampler is full it must be lifted and emptied, which with coal is a very dirty operation. The improvements which have been made consist in setting the frame firmly, at an angle of forty-five degrees, over a barrel, in an inclined support, which also serves as a cover for the barrel, and

in leaving the lower end of the longitudinal troughs open, so that they can clear themselves; also in providing an apron, at the lower end, to catch and guide the coal to a pan, as it slips down. This device is shown in Fig. 1.

The coal, which should be of a uniform size, is simply delivered in a thin sheet upon the face of the sampler, with a flat shovel. One half of it drops through into the barrel, where it requires no further handling, while the other half, which has been caught in the inclined troughs, simply slides down by its own weight into a pan provided to receive it. A sample of fifty pounds of coal, crushed to three eighths of an inch, can be accurately cut down to about twelve pounds in a few minutes, by simply putting it through the sampler twice. It can then be crushed much finer, and similarly cut down in a smaller sampler of the same type.

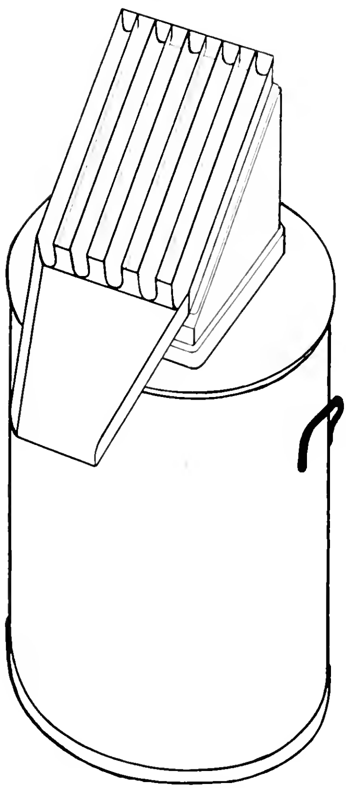


FIG. 1. SAMPLER.

The final sample should invariably be crushed and ground to pass an eighty-mesh screen, and should then be kept in tightly stoppered bottles.

Having obtained a fair sample of the coal the next step is to determine its calorific value. The merits and defects of the various calorimeters that are at present in use cannot here be considered, further than to say that practically all of them are worthless while one or two yield results that are, at best, only approximate.

The bomb calorimeters in which the combustion takes place in an atmosphere of oxygen gas, under pressure, are the only ones

that can lay claim to a fair degree of accuracy. The best known of these is the Mahler bomb calorimeter, brought out in 1893, a modified form of Berthelot's original calorimetric bomb. This has been, in some respects, improved upon by Atwater.

Mahler's apparatus consists of a bomb of forged steel whose exterior is nickel plated while its interior is coated with a thin lining of enamel which serves to protect the interior walls against the corrosive action of the acids which are formed during the combustion.

The coal to be tested is placed in a shallow platinum pan attached to the end of a light platinum rod which hangs from the under surface of the lid of the bomb, and it is in contact with a fine iron fuse-wire, which is connected to another similar rod. The fuse-wire may be kindled by means of an electric current and its combustion serves to ignite the coal. A heavy lid screws upon the outside of the neck of the bomb, and the latter can then be charged with about twenty-five atmospheres of oxygen gas, introduced through a long stem or pin valve, extending above the bomb, and closed by means of a thumbscrew. The bomb is placed in a calorimeter-can where it is partially covered with from 2 200 to 2 400 grams of water, which is stirred by means of an agitator, operated by hand with the aid of a lever. The combustion is instantaneous and complete, and the heat generated passes from the bomb to the water of the calorimeter, where it is measured. The calorimeter-can, which receives the bomb and the water used, is set within the customary water-jacket, which is intended to protect it as much as possible from draughts and the variable influences of the surroundings.

Accurate as the above instrument is in principle, there are numerous sources of error, which seem to have been overlooked, and many annoying defects of construction, which are serious. Aside from these, however, the errors which occur are, for the most part, small, while some of them are negligible. But, in the opinion of the writer, it is unwise to say that any error which can readily be prevented is negligible simply because such an error is small.

The defects of the apparatus appear to be the following:

1. The enamel lining, being a poor conductor of heat, causes

a trifling error from that cause; moreover, owing to the unequal expansion between enamel and metal, to which the apparatus is subjected when in use, it soon peels off. After about twenty combustions, imperceptible cracks occur which soon grow larger, corrosion sets in and the lining ceases to prevent the gradually increasing errors due to this corrosion.

2. The lid or cover, which screws upon the exterior of the neck of the bomb, is, of necessity, very heavy. It depends, for a tight joint, upon the sliding contact of an annular tongue of metal, projecting from its under surface, upon a ring-washer of lead, placed within a corresponding slot on top of the neck of the bomb. This method of sealing is somewhat defective and it does not invariably yield a tight joint.

The crushing of a lead washer, at the bottom of a slot, frequently also makes the cover bind, owing to the flow of metal.

3. The bomb is only partially immersed, even though as much as 2 400 grams of water have been used, so that losses of heat by conduction and radiation through the projecting stem must inevitably occur. No accurate correction for such losses can be made.

4. The amount of water employed, to only partially cover the bomb, is much too large, so that the range of temperature obtained, for a given unit of fuel burned, is smaller than is desirable.

5. The stirring of the calorimeter by hand is both awkward and tedious. It is well nigh impossible for a single operator to properly stir the calorimeter and take readings of the thermometer, on time, to one one-hundredth of a degree or closer, with any degree of certainty or accuracy. The stirring must be kept up for at least fifteen minutes and necessarily proceeds at a somewhat irregular rate, so that no correction for frictional effect of the stirrer can be correctly applied.

6. The crucible which holds the charge is too shallow, so that losses of coal by scattering, when oxygen is being admitted, or by spilling, owing to the vibration which may occur while the cover is being screwed on, are of frequent occurrence. These losses of fuel are not readily detected, so that errors resulting therefrom may occur and not be known.

Other minor defects also exist, such as the disadvantage of having to dip one electric wire under the surface of the liquid, in firing the bomb, while the other is touched to the bomb, and the disadvantage of employing an iron fuse wire for igniting the charge, which does not invariably burn to the same oxide, and whose heat of combustion must, therefore, be more or less uncertain; also the disadvantages due to miss-fires, which occasionally occur.

Finally, all open calorimeters are liable to errors due to exposure to the variable influences of the surroundings, whose temperature during an observation *can only be known approximately*. An error is also caused by evaporation of water from the surface of the open calorimeter-can, which, though small, can be avoided. The custom of only stirring the water jacket occasionally is also objectionable, as the temperature of this jacket varies at different points and cannot be accurately known. All corrections based upon such inaccurate readings must, therefore, leave much to be desired.

The above defects are, many of them, small, but some of them are important, while all of them can be remedied. The author, therefore, has thought it worth while to consider even the slightest.

Before describing the instrument which the writer has perfected he wishes to express his deep appreciation of the kindly assistance and advice afforded him by his friend, the late Prof. Silas W. Holman of the Massachusetts Institute of Technology, with whom the above work was originally planned and started, who encouraged and aided it in every way in his power. To him full credit is due for suggesting many of the most important features of the apparatus. Grateful acknowledgment is also made to Prof. Peter Schwamb, also of the Institute, who designed the body of the bomb and the sealing device which have been adopted.

The purpose of the author in constructing this calorimeter for his own investigations has been to produce an instrument that would be as nearly free from all the errors of existing calorimeters as it was possible to make it, and as convenient to handle as it could be made; in other words, to provide an instrument that would yield, in the hands of an expert, results of a degree

of accuracy hitherto unattainable. The calorimeter has been constructed, regardless of expense, with this sole object in view, and it is not too much to say that whatever statements are made in its favor are based upon actual results obtained in its use and all capable of absolute proof.

The instrument remedies all the defects to which attention has been called, while all operations which can be performed mechanically have been intrusted to the electric current.

The bomb is made of aluminum bronze, which transmits heat much more rapidly than steel. It is spherical in form, with the exception of a short neck through which it is charged and by means of which it can be sealed. The spherical form secures the maximum strength and capacity attainable, with the minimum weight and bulk of metal, so that the bomb requires less water to cover it, owing to its compact form, than if it had any other shape.

The bomb is closed by a lid, which is pressed directly downward by means of a nut which screws into the neck of the bomb and which bears upon a restricted area of the convex upper surface of the lid, quite near its center. The outer edge of this lid, underneath, where the area is greater, is brought into crushing contact with a light ring-washer of tin, resting upon a flat shoulder within the neck of the bomb. All twisting of the lid is thus avoided, and all binding due to the crushing of the washer is prevented, while a tight joint is invariably secured with but little effort. A light check-valve, which the interior pressure within the bomb forces upward, when the oxygen is shut off, serves to automatically confine the gas. The check-valve and closing nuts replace the long projecting stem or pin-valve of the Mahler bomb, and they are so disposed as to make it possible to completely submerge the bomb, so that no heat developed within it can escape measurement.

The calorimeter-can has a side chamber, adapted to exactly fit the casing of the electric stirrer, and a cover, which effectually prevents the escape of heat due to evaporation of liquid from the surface. The shape of the bomb and calorimeter-can are such that 1500 grams of water suffice to *completely cover* the bomb, an amount which is from 32 to 37 per cent. less than is required to only partially cover the Mahler bomb. In consequence

the range of temperature obtained by the combustion of a given weight of coal is much greater than Mahler obtains, being 4 degrees where he would obtain only from 2.52 to 2.72 degrees, and the small but unavoidable errors incidental to the reading of thermometers are thereby greatly reduced.

The outside of the bomb is nickel plated, while its interior walls are very heavily coated with pure gold, which protects them perfectly against corrosion and furnishes a sound and durable lining which transmits heat far more quickly and perfectly than enamel.

The finely pulverized coal is compressed in the form of a little disc in which a deep slot can be cut to facilitate its adjustment to the fuse-wire. The platinum crucible stand has a deep crucible within which the loop of platinum fuse-wire hangs, and upon which the single slotted lump of coal, weighing exactly 1 gram, can be slipped. From this it cannot get disconnected, for it is supported by the sides of the crucible. When all adjustments, which are readily made, are completed, the crucible stand is lowered bodily into the bomb, which is firmly held in a screw clamp, and the upper extremity of the crucible stand is adjusted to its side, in electrical contact with an insulated knob, outside of the bomb, through which an electric current may be conveyed to the fuse-wire. The arrangements are such that nothing can disturb the integrity of the adjustments when they are once made, so that miss-fires are of very rare occurrence. Moreover, the coal being in one piece, the crucible of deep form, and the crucible stand entirely in the bottom of the bomb, losses of fuel by scattering, when oxygen is admitted, or by spilling, cannot occur.

The stirring apparatus consists of an electric motor, held in position on a rod above the calorimeter, whose shaft, provided with propeller blades, is sufficiently prolonged to reach to the bottom of the calorimeter-can. The shaft revolves within a light metal casing, open above and below, in such manner that a rapid stream of water is drawn up from under the bomb and is thrown out above and around it. The stirring is rapid and perfect, and requires no attention whatever, while the speed of the propellers is sufficiently constant to have made it possible to determine

with the greatest accuracy the exact frictional effect of the stirrer and to apply the proper correction therefor to the determinations.

Finally, the water jacket, which surrounds the calorimeter, not only has the usual outside covering of felt and enamel cloth but has also been provided with a heavy cover of non-conductive material of its own, so that the space within which the operations and measurements are conducted is absolutely protected against the influence of the surroundings, and is only exposed to such influences as can definitely and accurately be known. To make doubly sure of this, the water jacket is provided with an electric stirrer of its own so that its true temperature at all times is no longer open to doubt.

The bomb having been charged, placed within the calorimeter-can, covered with a known weight of water, both covers put on and the thermometers adjusted, the two electric stirrers are set in motion and the stirring takes place automatically. The influence of the water jacket upon the calorimeter is carefully observed and, when it is found to be uniform, the charge is fired. The rise of temperature during the combustion is noted through a series of readings until the maximum is reached and the readings are continued after the maximum, to determine the after influence of the water jacket upon the calorimeter. Proper correction is made for the amount of heat introduced through the fuse-wire, the melting of which is timed with an accurate stop watch, from the dropping off of the needle of an ammeter placed in circuit.

After the combustion, the bomb is removed from the calorimeter, placed in the screw clamp, the products of combustion drawn out, and analyzed, if desired, to prove that the combustion was complete, the acids formed by the combustion washed down and carefully drawn out and the nitric and sulphuric acids formed determined by appropriate methods. A somewhat elaborate calculation is now required to correct the determination for the influence of the surroundings, acids formed, fuse and stirrer, but these corrections can all be made with the utmost precision, by calculation from the very accurate and reliable data which have been obtained. In short, a result is obtained which accurately and positively indicates the true calorific value of the fuel, without

loss of any kind, provided that the accuracy of all the instruments used has been carefully verified.

The above instrument, therefore, furnishes us the means of determining with very great accuracy the true calorific power of combustibles, it being assumed, of course, that all the precautions which have been pointed out as necessary in securing the samples have been taken.

The writer has suggested that the only sure and logical manner of purchasing coal is on a basis of its quality, as shown by analysis, and its correct fuel value by calorimeter test. This work is exclusively the work of the coal specialist, for many reasons; partly because he is best fitted to do it accurately, partly also because his position between the two parties is that of an umpire. Aside from the fact that such work as has here been described is seldom done with even an approximation to correctness, the fact remains that neither the sampling nor the calorimeter test of either the producer or the consumer can be reciprocally acceptable to the other. Two examples taken from the writer's experience may serve to make this clear.

A certain lot of 10 000 tons of " Pocahontas " coal was objected to by a consumer, on the score of clinkers. The coal dealer and the consumer sampled it together, taking out a sample weighing 65 pounds, and the request was made of the consumer to send the sample to the writer's laboratory. But, for some reason, which opens up a field for speculation, he sent only $10\frac{3}{4}$ pounds. The analysis showed:

Ash . . . . 28.63 per cent.

Numerous analyses of Pocahontas coal, made by the writer, show that this coal generally carries on an average:

Ash . . . . 6.16 per cent.

Agreement upon the basis of 28.63 per cent. ash being out of the question, the writer was called upon to sample the lot of coal systematically, the result showing:

Ash . . . . 10.62 per cent.

This result while showing that this lot of coal was not up to its average quality also serves to show the unreliability of the sample sent by the consumer.

Again, the writer has analyzed the same coal as furnished for test runs on cruisers. Every lump passes through the hands of three men who reject any one containing the slightest trace of impurity; the coal is then shipped in bags. This coal showed:

Ash . . . . 1.65 per cent.

Yet there are many published analyses of coals showing even less ash than the above extraordinary result, which the coal dealers seriously ask us to believe fairly represent the quality of the coal.

These results, from the two different points of view, simply show that the sampling or analysis of the two interested parties, however well done, can never afford satisfactory ground upon which they can meet.

The question must be settled by the coal chemist, or specialist, *acting as an umpire*, and the accuracy with which his work is performed should serve as a guaranty of fairness to both parties.

The system which has here been suggested is perfectly practical and fair, and the writer is convinced that all large purchases of coal will soon be made on that basis.

DISCUSSION.

PRES. E. C. BROOKS. We have listened with a great deal of interest to this paper, and I should like it if some of our members who are familiar with the subject would give us the benefit of some discussion.

MR. ROBERT SPURR WESTON.* Mr. President, Mr. Williams has so well covered the whole ground in such an authoritative manner and with such detail and care, that it seems superfluous for the speaker to make any remarks on the subject.

One little point, however, comes to mind, namely, the percentage of a fuel which can be utilized. It has always seemed that we should do a great deal more analytical work on the material left in the ash pile than we have done. The subject is somewhat analogous in this respect to the feeding of human beings. We know that certain foods which have higher calorific values than others do not support the body as well as others of lower values.

* Sanitary Engineer and Expert, Boston, Mass.

simply because the body utilizes a smaller percentage of the richer foods than it does of the poorer. Therefore, it seems to the speaker that we should also study the coal with respect to the boilers that it is to be used under, because certain coals will be more economical to use with certain steam plants than they will with others, independently in some measure of their thermo-chemical value. If we knew the fuel value of the ash from our large steam plants, we should be able to judge the value of the coal to the consumer more accurately. This, however, has to do with the combustion, not the purchase, of fuel.

I think that the position of the author, Mr. Williams, is very well taken, that all large quantities of coal should be purchased on the basis of the analysis rather than on that of the brand of coal. Mr. Williams has contributed a most interesting and useful paper, and all, especially those of us who have done laboratory work, can testify to the skill of his demonstration.

THE PRESIDENT. I would say in regard to what Mr. Weston has said about the ash pile, that I think it only requires a very casual inspection of lots of ash piles to see that the value of the fuel, a large part of it, at least, is out on the dump.

MR. EDWARD ATKINSON.* Mr. President, knowing nothing of physics or chemistry, it is perhaps unbecoming for me to say anything. My memory probably goes back further than that of any other man as to the practical application of fuel in the steam cotton mill, recalling, as I do, the first steam cotton mills that were built. At that time, of course, the practice was all empirical, and buyers bought only lump anthracite coal, thinking that the best, and from that we have come down to the refinement so accurately presented by Mr. Williams. When I was a buyer of coal on a large scale, more than twenty-five years ago, I began to take notes of all the various devices and of all the merits of one kind of coal and another, and presently I thought I would compute them together. I found that if I adopted the coals one after the other by which I was to save twenty-five cents a ton, and then applied the various devices for saving in the use of that coal, I should get to the point where my coal would cost me nothing, and I should be paid a bonus for taking it.

* President, Boston Manufacturers Mutual Insurance Company.

Later I took charge of the Boiler Mutual, and then I found that I ought to know a little more than I did, and I had to pick out men who knew more than I did, in order to conduct my part. My first point there was to find out something about the relative consumption of coal in different establishments. I adopted my customary plan of agreeing not to disclose the names of any of my clients, and I sent out circulars to a large number. They were using all the various devices, down draft and coal savers and smoke consumers, and all those things. I obtained statements ranging all the way from 1.1 pounds per horse power to 5 pounds, and I found that there was no relation one to the other, either in the devices that they used for saving fuel, or in automatic firing or hand firing, and that there was no real basis to be established from comparison or practice. All those results have been tabulated in one of my reports, and I will send a copy of that report to any member of the Association who will drop me a postal card.

Then came up the calorific value of coals. I took, not the refined methods that have been shown here to-day, but I chose my consulting engineer, Mr. R. S. Hale; tests were made with the bomb calorimeter for establishing an average range of the calorific value of the different types of coal which are offered in this market, by which in an approximate manner the relative value of the average coal offered under different names could be established. We took Pocahontas coal as the standard of one hundred and compared with that all the different types of coal now offered hereabouts. That has all been tabulated, and I have that report and will send it to any member of the Association who will drop me a postal card.

All these things are interesting and of the utmost importance. There can be no doubt whatever that coal should be bought only after careful examination, especially in large quantities, either of the most refined character, or in a general way so as to reach as close a result as can be obtained. This course will be necessary during the temporary use of coal in New England. I think the use of coal for steam boiler purposes is rapidly passing, and I expect to see gaseous fuels and the gas engine rapidly take its place for stationary purposes.

Mr. Edward W. Bemis.* I do not feel competent, Mr. President, to discuss the theoretical aspects of this valuable paper. All I can say directly upon it is that we believe in the principle of this testing of coal, and apply it when we purchase coal for our water works in Cleveland. We are buying three or four cars on the average every day throughout the year, usually Pittsburg slack, and every car is tested. We have an agreement with the companies from which we buy — just now it is with the Pittsburg Coal Company, last year it was with another — by which they agree to abide by our determinations. But I have often thought it would be fairer if there were some scientific laboratory in our city where the determinations could be made. At the time when coals are offered in competition for the contract for the year, we have a full test, an eight-hour run of the coal, and the bidders in competition for the contract have to agree to furnish coal equally good throughout the year, so we make their samples the standard. And then whichever company is finally awarded the contract, it is on the basis of the value of its coal as shown in the full test and also in the calorimeter test, and the company is under a contract to allow us to reduce the price proportionately to the results of our tests from time to time as compared with the sample car. We do not give them an increased price for better quality, but they agree to abide by the conditions of the specifications, which provide that there shall be a reduction for poorer quality. It is understood, however, that it shall not be made on very small percentages, but only when in our judgment there is a marked falling off. Of course the more accurate methods which have been detailed here to-day would be very valuable for us, but we do not happen to have in Cleveland a laboratory outside of the water works, except a commercial one. There is one that we used for two years, but that is simply a private laboratory that tests coal, and we finally decided that we preferred to do it in our own laboratory. If there were a laboratory connected with the Western Reserve University, we should be glad to avail ourselves of it.

Mr. Atkinson. Isn't there one at the Case School?

Professor Bemis. There is a laboratory at the Case School

* Superintendent of Water Works, Cleveland, Ohio.

where they have tested coal, but they don't do it commercially yet, at least on any large scale. Professor Benjamin and others talked about establishing a department, I think, some months ago, but I have heard nothing about it since.

Mr. Atkinson. I will state that the case where I found an expenditure of 5 pounds of coal per horse-power on an annual consumption of 30 000 tons wasn't very far from Cleveland. I think they need something of this kind out there.

Professor Bemis. They certainly do.

Mr. Williams. May I inquire on just what basis the reduction in price is made? For instance, supposing one car load is furnished and is satisfactory and the price is settled on that; on what basis is the reduction made, and how great is the reduction in case the coal does not come up to the standard of the car load?

Professor Bemis. Thus far we have taken the average for each month and only make a reduction in case the average falls below to a considerable degree. During the three years in which we have tested every car we have only found it necessary to dock the coal company on three or four cars. This method, of course, is not entirely fair to us, because the value of the coal would fall off to a very much larger percentage than the percentage of B. T. U.'s. However, we have made a reduction occasionally, which tends to keep the company up to time. The fact that we are testing every car is itself a very good check.

Mr. Williams. I wished to know if the reduction is exactly proportional to the decreased heating power? For instance, if the quality of coal agreed upon costs $2.00 per ton and the quality delivered shows only 90 per cent. of the heat units of the standard, do you pay only 90 per cent. of $2.00 per ton?

Professor Bemis. That is the idea in the contract. In deciding how to award the contract at the start, we go into a very exhaustive analysis, by an eight-hour run, taking one car one day and another car the next, and the agents of the companies are allowed to be present while their sample car is tested. The agents have to agree that the coal furnished is a fair sample of the coal, and each company has to specify the mine from which the coal is to be furnished, and the agent of the company agrees that the coal furnished is a fair sample of the slack coal from that mine. Before

we begin to test we have that agreed to by the competitors. Then we have a run with our engineers and with theirs present, and on the result of that is figured out which coal, taking into account the value of .the coal for making steam, is the cheapest. Of course, we also run the coal for a few days after the test to see how it acts on our grates, to see whether it works up satisfactorily in every way, and usually it does.

Mr. A. O. Doane.* At the Metropolitan Water Works for the past few years we have made tests of coal, and while they may not have been absolutely accurate, the result has been very satisfactory in the quality of coal furnished. The moral effect of testing was good, as the dealers, knowing that the coal was to be tested, have been a little shy about trying to put off on us any poor coal. We test the coal that is offered by different dealers, and do not depend on any small sample which is sent in, but if possible find where a cargo of the coal has been delivered, go there and get a sample in much the same way Mr. Williams has described; that is a great point, to get a representative sample, then we make a test and also get all possible information from parties who are using the coal as to how it burns on the grates; because the calorimeter, while it determines the amount of heat units present or the calorific power of the coal, does not determine in all cases whether the coal is suitable for a particular plant or not. The particular type of boiler in use may give better results with one kind of coal than another, so that point is always looked into.

I should like to say something about specifications. Many specifications call for a coal which is equal to some well-known brand, but that of course is rather indefinite. That is, we may specify equal to George's Creek, but who knows exactly what George's Creek is? It varies considerably, and you need really to specify the mine and the shaft; I have thought for a long time that something of a more scientific nature would be much better. I should like to ask Mr. Williams if he has any general specification in mind, or whether it would be feasible to make a general specification on a scientific basis that people could use in buying coal.

* Division Engineer, Metropolitan Water Works, Boston, Mass.

MR. WILLIAMS. I believe that it is entirely feasible to lay down specifications for buying coal, based upon its quality and heating power, that would result in large economies and that would be perfectly fair to both parties. An actual example of the manner in which the scientific results can be practically applied will serve to make this clear. The United States Government is now buying all of its coal for public buildings on the basis of heat units, determined in one of my calorimeters, established some years ago at Washington. Some $220 000 worth of the best steaming coals are contracted for at one time.

The dealers originally furnished selected samples of the kind of coal which they agreed to deliver and the award was made by simply looking at the samples. It is quite impossible to obtain definite knowledge of the value of any coal by simple inspection, much less to discriminate between two coals of nearly the same quality but of slightly different appearance. It is a fact, however, that, in spite of the agreement, the quality of coal delivered seldom came up to that of the samples submitted with the bids. The next time that these were sent in, the fuel value of all the samples submitted was determined, and the contract was awarded to a coal showing 15 000 B. T. U. per pound and costing $3.00 per ton. Deliveries of 12 000 or 15 000 tons at a time then began to be made. These also were carefully sampled and analyzed, showing, we will say, only 12 000 B. T. U. per pound. The agreement calling for coal of 15 000 B. T. U., the Government simply paid for what it received: viz., twelve-fifteenths of $3.00, or $2.40 per ton. In four months the saving amounted to fully $8 000, at an estimated expense of less than $500. The above is an actual example.

There seems to be no reason whatever why, within reasonable limits, the producer should not be required to furnish exactly the grade of coal specified, and the price settled to fit the quality.

This would undoubtedly result in an enormous saving to the consumer who would get *uniform coal*, which he could handle with greater economy, and who would also *get what he pays for*. It would seem incredible that a system so just and whose advantages are so apparent has not long ago been put in practice, were

it not for the many confusing, but not generally understood difficulties, which have stood in the way. These difficulties, however, are now very nearly under control, and there seems to be no valid reason why consumers *should continue to purchase coal with their eyes shut*, and suffer the consequences, unless they really prefer to do so.

For those who do not, the following plan, among many which might be proposed, seems to the writer to be the simplest for making a practical use of the scientific results in purchasing coal in large quantities:

Specification.

1. For the producer and the consumer to agree to abide by the results of the analysis and calorimeter test of the coal, which, however, should be performed with the degree of accuracy which has been shown to be necessary, so that the result may be conclusive.
2. Then to agree upon a method of sampling the coal, following substantially the lines that have been laid down, that shall make it possible to secure a thoroughly reliable representative sample of the coal.
3. To perform this sampling in the presence of a representative of each party interested, the same as is done when valuable lots of rich ore are being sampled.
4. To send the sample for examination to a coal specialist of acknowledged reputation, acting as an umpire, who alone is capable of furnishing the reliable and conclusive results which both parties can accept.

Where facilities for fine pulverizing of the coal do not exist, samples of from 20 to 25 pounds should be sent, but where the work can be properly carried to completion, samples as small as *two ounces*, or even less, *which can readily be forwarded by mail*, with little or no delay, are sufficient.

It makes very little difference, therefore, whether the laboratory where the information can best be obtained is situated in Boston or in San Francisco, its results are readily available to all, and the advantages which result from the application of such a system, whether carried out in the manner suggested or in a slightly modified form, are so apparent that they seem to fully justify all that the writer has said upon the subject.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, Mass., December 14, 1904.

President Edwin C. Brooks presiding.

The following members and guests were present:

Members.

S. A. Agnew, Edward Atkinson, C. H. Baldwin, L. M. Bancroft, J. E. Beals, E. W. Bemis, F. D. Berry, J. M. Birmingham, E. C. Brooks, Frederick Brooks, George Cassell, G. F. Chace, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, G. E. Crowell, A. W. Cuddeback, A. O. Doane, L. S. Doten, C. R. Felton, F. F. Forbes, A. D. Fuller, A. S. Glover, F. W. Gow, J. O. Hall, L. M. Hastings, V. C. Hastings, T. G. Hazard, Jr., Allen Hazen, D. A. Heffernan, H. G. Holden, W. E. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, J. W. Killam, G. A. King, L. P. Kinnicutt, E. S. Larned, J. W. Locke, H. V. Macksey, D. A. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, A. S. Merrill, F. E. Merrill, E. M. Peck, H. E. Perry, J. B. Putnam, W. W. Robertson, C. W. Sherman, G. H. Snell, G. A. Stacy, J. T. Stevens, C. N. Taylor, R. J. Thomas, W. H. Thomas, D. N. Tower, W. H. Vaughn, C. K. Walker, R. S. Weston, F. B. Wilkins, F. I. Winslow, G. E. Winslow. — 65.

Honorary Member.

Desmond FitzGerald. — 1.

Associates.

H. A. Desper; H. L. Bond & Co., by Harold L. Bond; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Greenwood & Daggett Co., by George F. Chace; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden and Walter A. Hersey; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by F. B. Mueller and W. L. Dickel; National Meter Co., by Chas. H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Rensselaer Mfg. Co., by F. S. Bates and C. L. Brown; Ross Valve Co., by Wm. Ross; George H. Sampson, by W. T. Page; A. P. Smith Mfg. Co., by F. N. Whitcomb; Sumner & Goodwin Co., by H. A. Gorham; Thomson Meter Co., by S. D. Higley; R. D. Wood & Co., by Wm. F. Woodburn. — 23.

GUESTS.

Hon. F. R. S. Mildon, Mayor, and George R. Hall, Marlboro, Mass.; J. J. Moore, Hingham, Mass.; H. S. Brown, Boston, Mass.; and W. H. Van Winkle, of the Water Works Equipment Co., New York City. — 5.

(Names counted twice. — 3.)

THE PRESIDENT. I have been asked to appoint a member of the Committee on Meter Rates to fill the vacancy caused by the death of Mr. George P. Wescott, and I will name Mr. Charles F. Knowlton of Quincy.

MR. CHARLES K. WALKER.* Before we proceed to the regular business of the afternoon, Mr. Chairman, I want to say a little something. Here is a recommendation which was sent to Manchester by insurance people. It came in a letter from the office of the National Board of Fire Underwriters.

NEW YORK, November 10, 1904.

MR. CHARLES E. MANNING,

President Board of Water Commissioners, Manchester, N. H.

Dear Sir, — We now hand you, at the suggestion of our inspector, a copy of the recommendations relative to improvements in the Fire Department and water supply of Manchester, and asking your co-operation in securing the same, remain,

Yours truly,

(Signed) H. K. MILLER,

General Agent.

"SUMMARY OF RECOMMENDATIONS," MANCHESTER, N. H.

Inspected, December 21, 1897. Reinspected, October 19, 1904.

FIRE DEPARTMENT.

1. There is a necessity for the organization of an additional fire company to consist of 1 permanently employed captain, 1 engineer for steamer and 2 drivers, also 10 call service firemen, 4 horses, equipped with 1 second-class steam fire engine, 1 combination and chemical hose wagon with double 35-gallon cylinders, at least 2 000 feet of first-class fire hose and service appliances. This company should be suitably located at the vicinity of Hall and Silver streets. Building improvements are rapidly increasing, also extensive shoe manufactories located nearby, and without adequate protection from the city service.

2. All electric fire-alarm wiring should be placed in an underground conduit, to insure safety from damage by storms and high winds.

* Superintendent of Water Works, Manchester, N. H.

3. The present storage battery of fire-alarm system should be strengthened or replaced by an improved new battery.

4. The requirements of the ordinance prohibiting the erection of wooden buildings and frame out-structures within the established fire limits, should be strictly enforced.

WATER SUPPLY.

1. The entire amount of 20-inch diameter, cement lined force main should be replaced by standard cast-iron pipe.

2. Owing to the uncertainty of the flow of water from the lake, to operate the water-power pumps, there is a necessity for installing one steam-power pumping engine, capacity of 8 000 000 gallons per diem, at the low-service station for reserve or emergency service.

3. The present use $2\frac{1}{4}$-inch diameter hose connections on fire-service hydrants should be replaced by standard $2\frac{1}{2}$-inch diameter hose and steamer, connecting discharge outlets, to insure quick service and an increased flow of water.

Now, I want to tell you, gentlemen, that it would cost $250 000 to do this work, and that is considerable money for Manchester. We have a supply from the high service with all cast-iron pipe, but the fire insurance companies want us to lay out $250 000. Well, I think they had better get out. (Laughter.) They have had all the water they wanted up to this time, they have had an abundant water supply, and they have had good luck. For an insurance company to come into the city of Manchester and tell us what to do is something I can't understand. I don't think it is right and I don't think it is fair, when they have had all the water they wanted, for them now to ask us to spend $250 000 more. I have brought this to your attention, gentlemen, so you can think it over and tell the citizens of Manchester what they ought to do. I have read this so you can see what we have to contend against. We have about so much money and so many water takers, and we want the plant to pay for itself, and we want to keep within our means. We don't propose to run into debt because some fire insurance company comes up there and tells us what we ought to do.

MR. WILLIAM ROSS. They told us in the city of Troy that we would have to spend so much money or they would put a little pink slip on our policies.

MR. EDWARD ATKINSON. I would ask the gentleman from Manchester to discriminate a bit when he speaks of insurance

companies, and tell us what kind of insurance companies they were. I should like to know where these demands came from.

Mr. Walker. I am glad Mr. Atkinson is after me, because I am after him. (Laughter.) There is no place in the New England states where they have better fire service than in Manchester, N. H., and I know there has been all the water that was needed in case of fire. Now, we don't propose to give the insurance folks all there is in the city.

Mr. Atkinson. The factories in Manchester that I am connected with have had an ample supply of water that they have provided for themselves.

Mr. Walker. I am glad of it.

The Secretary read the following communication:

METROPOLITAN WATER BOARD.

Chief Engineer's Department,

Savoy Court, Strand, London, W. C., November 28, 1904.

Dear Sir, — I am exceedingly obliged to you for your letter dated November 17 informing me that I had been elected as an honorary member of the New England Water Works Association. Will you please convey my thanks to your Association, and state that I am exceedingly pleased to be elected an honorary member.

Yours truly,

(Signed) William B. Bryan.

George E. Gilchrist & Co. of Boston, manufacturers and jobbers of steam, gas, and plumbing materials, were elected to associate membership.

The first paper of the afternoon was presented by Leonard S. Doten, civil engineer, Quartermaster's Department, United States Army, Boston, Mass., it being "A Description of the Concrete-Steel Water Tower and Standpipe at Fort Revere, Hull, Mass." The paper was discussed by Edward Atkinson, F. L. Winslow, A. O. Doane, and Charles N. Taylor.

Mr. Henry J. Williams, chemical engineer, Boston, Mass., read a paper entitled, "The Advantage of a Scientific Basis for Determining the Value of Fuels," and gave a practical demonstration of a calorimeter test. On motion of Mr. Charles W. Sherman, a vote of thanks was tendered to Mr. Williams. The

subject of the paper was discussed by Messrs. Robert S. Weston, Edward Atkinson, Prof. Edward W. Bemis, and Mr. A. O. Doane.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 11, 1905.

President Brooks in the chair.

The following guests and members were present:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, J. E. Beals, J. F. Bigelow, J. W. Blackmer, George Bowers, E. C. Brooks, G. A. P. Bucknam, J. T. Cavanagh, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, J. W. Crawford, L. E. Daboll, E. R. Dyer, H. P. Eddy, G. E. Evans, J. N. Ferguson, F. F. Forbes, F. L. Fuller, A. S. Glover, W. J. Goldthwait, J. W. Goodell, J. W. Griffin, J. O. Hall, J. C. Hammond, Jr., D. A. Hartwell, D. A. Heffernan, G. W. Hawkes, F. W. Hodgdon, H. G. Holden, E. J. Johnson, Willard Kent, F. C. Kimball, G. A. Kimball, G. A. King, Horace Kingman, E. S. Larned, J. W. Locke, Hugh McLean, H. V. Macksey, A. E. Martin, W. E. Maybury, A. S. Merrill, F. E. Merrill, Leonard Metcalf, H. A. Miller, J. F. J. Mulhall, F. L. Northrop, O. E. Parks, H. D. Parsons, E. L. Peene, J. W. Smith, C. W. Sherman, G. H. Snell, G. A. Stacy, J. T. Stevens, J. J. Sullivan, R. J. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, W. J. Wetherbee, J. C. Whitney, F. B. Wilkins, G. E. Winslow, E. Worthington, Jr., F. W. Dean. — 69.

Honorary Member.

Desmond FitzGerald. — 1.

Associates.

Henry A. Desper; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by Fred'k N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Hart Packing Co., by Horace Hart; Hersey Mfg. Co., by Albert S. Glover, H. D. Winton and Walter A. Hersey; The Fairbanks Co., by F. A. Leavitt; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by W. L. Dickel; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates and C. L. Brown; Ross Valve Co., by William Ross; A. P. Smith Mfg. Co., by F. N. Whitcomb; Sumner & Goodwin Co., by H. A. Gorham; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop and W. F. Hogan; U. S. Cast Iron Pipe & Foundry Co., by W. B. Franklin; Walworth Mfg. Co., by George E. Pickering; R. D. Wood & Co., by Wm. F. Woodburn. — 29.

GUESTS.

Mrs. Edwin C. Brooks, Cambridge, Mass.; Mrs. George Bowers, Lowell, Mass.; Mrs. H. G. Holden, Nashua, N. H.; Mrs. John C. Chase, Derry, N. H.; Mrs. Ida H. Proctor, Lowell, Mass.; Mrs. R. C. P. Coggeshall and Miss Helen R. Coggeshall, New Bedford, Mass.; Miss Mabel A. Bancroft, Reading, Mass.; Mrs. Charles W. Sherman, Belmont, Mass.; Mrs. George E. Pickering, Mrs. George A. Kimball, Somerville, Mass.; Mrs. George A. Stacy and Mrs. James F. Bigelow, Marlboro, Mass.; Mrs. F. F. Forbes, Brookline, Mass.; Miss Almira Winslow, Waltham, Mass.; Mrs. H. P. Eddy, Mrs. Henry A. Desper, Miss F. W. Desper, Worcester, Mass.; F. S. Dewey, P. M. Austin, water commissioner, C. N. Oakes, clerk water board, Westfield, Mass.; Miss Alice S. Corner, Holyoke, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mr. and Mrs. Theodore Moorehead, Brookline, Mass.; Mr. and Mrs. Henry J. Williams, Mr. M. C. Hight, Mrs. A. H. Virtue, Boston, Mass.; Mrs. F. W. Dean, Lexington, Mass.; Mrs. L. E. Daboll, New London, Conn.; Mr. A. E. Blackmer, Plymouth, Mass.; Mr. Charles A. Van Keuren, chief engineer, Jersey City, N. J.; Mr. John H. Cook, Passaic, N. J. — 34.

(Names counted twice — 3.)

PRESENTATION OF GAVEL.

MR. JOHN C. CHASE. Mr. President, it lives in the traditions of an ancient fraternity, whose records are by no means inscribed in water, that the gavel is an emblem of authority and should be in the hands of all who are called upon to preside over deliberative bodies. For more than a score of years the President of this Association has been without the dignity conferred by the emblem of his high official position. The omission has not been unnoticed, and as an artificer in wood as well as a purveyor of water, it gives me pleasure to provide this gavel, and ask its acceptance by the Association.

The wood from which it is made comes from a far distant state, which was for many years my home. It is also from the one-time estate of Cornelius Harnett, a noted Revolutionary patriot, whom Josiah Quincy visited in 1770 and styled in his Memoirs as the "Sam Adams of North Carolina." Thus again, after the lapse of a century and a third, Massachusetts and North Carolina touch hands. It is a piece of water oak, a tree that in its nature and habitat naturally suggests the sturdy character and growth of our Association and the important natural element in whose procurement and distribution for public supplies and the safe-guarding of its purity and plenty we are all deeply interested.

And now, Mr. President, I place this gavel in your hands. A

badge which I have seen upon your person indicates that you have been instructed in its proper use. (Applause.) During the brief time, unfortunately, in which you will have the privilege of wielding it I am certain that it will be used with credit to yourself and satisfaction to those over whom you have the honor to preside, and transmitted in due time to your successor. (Applause.)

The President. Mr. Chase, in behalf of the Association I thank you sincerely for this beautiful and appropriate gift. I have pounded the table during the last year with a knife handle, as my predecessors have done before me, and I am glad that hereafter the President of this Association will have a more fitting implement. I have had in mind that, should I live to get through with my duties as President, unless some one else in the meantime should have done so, I would present the Association with a gavel, but I am pleased to have had my intention so well anticipated. I assure you I shall try to use this gavel with moderation in the few minutes remaining for me to use it and then will gladly transmit it to my successor. (Applause.)

The following applications for membership were reported as having been properly approved by the Executive Committee:

Resident. — Richard K. Hale, Brookline, Assistant to Robert Spurr Weston, Sanitary Engineer; Henry J. Williams, Boston, Chemical Engineer and Expert on Fuels; Charles T. Main, Winchester, Chairman of Water Board.

Non-Resident. — W. W. Berry, Centerville, Iowa, Superintendent of Centerville Water Works.

On motion of Mr. Coggeshall the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared elected members.

President Brooks then delivered his annual address.

President's Address.

Gentlemen of the New England Water Works Association, — At the close of the year it is fitting that we should review the events of the past year and note the progress made. In doing so I congratulate the Association upon its continued prosperity and the unflagging interest taken by the membership as shown by the attendance at our meetings.

Our membership has suffered a loss by death of 16 during the past year, 14 members and 2 associates. For obituary notices, I would refer you to the JOURNAL, where a brief account of their work will be found. Our membership to-day is 604, compared with 586 of the last year, showing quite a substantial gain.

The financial affairs of the Association are in a very satisfactory condition, although not showing on the face quite as well as the last year; still, an analysis of the same will reveal the fact that extraordinary expenditures were met this year which were properly chargeable to other years.

The JOURNAL fully maintains the high character which it has held for past years, and it should be a source of pride to the Association that its standing among the scientific journals of the country is such as it is, and too much praise cannot be given to our Editor, Mr. Sherman, and his good work in connection therewith.

The usual meetings have been held the past year at this hotel and have been very fully attended.

The summer excursion to Nantasket was a perfect success, and the fall excursion to Holyoke resulted in a larger meeting than was ever held before by the Association. I think we should all join in heartfelt thanks to the water-works officials and to the people of Holyoke who so generously contributed in every way to the success of our fall meeting.

The papers presented during the year have been of more than usual interest and embrace among their number many that will be sought by the engineering world for the information contained therein.

I wish to commend the Executive Committee for their regular attendance at the meetings and for the help they have been to me during the past year.

Our Secretary has been ever zealous in forwarding the aims and ends of the Association, and to him too much praise cannot be given.

Our Advertising Agent has shown his usual energy in soliciting advertisements, and the pages of the JOURNAL show the result of his work.

It was hoped at the beginning of the year that more time might be given at the meetings to the matter of topical discussion; it

seems to be the feeling with a large portion of the membership that in that particular part of the work of the Association they are most interested and from it derive most benefit. The time at our disposal at the meetings prevents anything like a lengthy discussion, unless the papers read are extremely short. Will it not soon be necessary for us, in order to increase the usefulness of the Association, to give more time at the meetings, and have a fuller discussion of the papers, to have all the papers printed and distributed among the membership before the meetings so that the members can be prepared for a discussion of the same? The papers need thus be read only by title, and absent members can present written discussions to be read by the Secretary. In many cases where a member cannot be present a written discussion by him may add very much to the interest of the papers presented. I make this suggestion hoping that it may be considered the coming year.

The committee having charge of the question of water used by private fire supplies has certainly succeeded in attracting widespread attention to the subject, and I earnestly hope that a very full and thorough discussion may lead to some satisfactory solution of this very vexing question.

The past year a committee on uniform sizes of threads for hydrants and hose connections has been appointed. This is a matter which is of great importance in cases of great conflagrations where fire apparatus is called from neighboring cities; and although the subject has long been discussed by different bodies, with as yet little success, let us hope we may be able to accomplish something at least in that direction.

The committee on meter rates has a subject under consideration which is of great interest to water-works people all over the country. They will certainly deserve our thanks if they are able to add something to the solution of this very troublesome question.

The committee recently appointed on subjects for the meetings will be of great help to the officers of the Association and certainly add much to the interest and value of our meetings.

The present occasion offers another of the innovations in the regular proceedings of the Association, and from the attendance I think we can say that the experiment bids fair to be a success.

It is always a pleasure to have the ladies with us at these gatherings, and I think this midwinter gathering with them will certainly be looked forward to by many as one of the delightful occurrences of the year.

In retiring from the chair, I wish to thank the officers, members and associates for the cordial support they have given me during the past year, and I earnestly hope they will extend the same to my successor.

Mr. Stacy. If you will allow me a moment, Mr. President. Before we proceed further with the regular order of business it seems to me we ought to take some formal notice of the very useful and beautiful gift that has been made to the Association by one of our most earnest and interested members, and I therefore move that the thanks of the Association be extended to Mr. Chase for the gavel which he has so kindly presented. Adopted.

The Secretary, Mr. Willard Kent, submitted the following report:

Report of the Secretary.

Mr. President and Gentlemen of the New England Water Works Association, — I have the honor to submit the following report of membership, receipts and disbursements of the New England Water Works Association for the year ending December 31, 1904:

Membership.

The total membership of the Association January 1, 1904, was . .	586
The present membership is	604

The membership is divided as follows:

MEMBERS.

January 1, 1904.	Total active membership		528
	Withdrawals:		
	Transferred to Honorary list	4	
	Resigned	10	
	Died	14	
	Dropped	1	29
			499

	Initiations:			
	January	3		
	February	8		
	March	5		
	September	14		
	November	5	35	
	Reinstated		4	538

HONORARY MEMBERS.

January 1, 1904.	Honorary members	3	
	Elected	1	
	Transferred from members' list	4	8

ASSOCIATES.

January 1, 1904.	Total associate membership		55	
	Withdrawals:			
	Resignations	3		
	Died	2	5	
			50	
	Initiations:			
	January	2		
	February	1		
	September	4		
	December	1	8	58
January 1, 1905.	Total membership			604

SUMMARY OF RECEIPTS AND DISBURSEMENTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR 1904.

RECEIPTS.

Dues	$2 398.24
Advertisements	2 020.56
Initiations	242.00
Subscriptions	155.25
Journals sold	94.30
Sundries	82.60
June excursion	246.00
	$5 238.95

DISBURSEMENTS.

Journal (including membership list and index)*	$2 383.82
Stationery	472.18
Rent	400.00
Assistant Secretary	385.00
Editor	300.00
Advertising Agent	282.75
Reprints	221.00
Stenographer	209.50
Incidental expenses	201.10
Secretary	200.00
Stereopticon	68.43
Music	54.00
Badges	36.00
Exhibit	18.13
June excursion	296.00
Total	$5 528.21
Expenditures in excess of receipts *	$289.26

At the present time there is due the Association:

For dues	$321.75
For advertisements	483.75
For sundries	30.45
	$835.95

I know of no outstanding bills against the Association.

Respectfully submitted,

WILLARD KENT, *Secretary.*

On motion of Mr. Chase the report of the Secretary was accepted and placed on file.

The Treasurer, Mr. Lewis M. Bancroft, submitted the following report:

* Expenditures during the year include the cost of December, 1903, JOURNAL as well as the four issues of 1904, whereas receipts include returns from advertising for four issues only.

LEWIS M. BANCROFT
In account with the New England

RECEIPTS.

1904.				
January 12.	Balance on hand			$3 069.05
August 1.	Dividend, People's Savings Bank			52.40
December 3.	Dividend, Mechanics Savings Bank			36.96
February 22.	Received of Willard Kent, Sec'y . . .		$1 490.42	
April 21.	,, ,, ,, ,, . . .		816.57	
May 24.	,, ,, ,, ,, . . .		337.55	
June 12.	,, ,, ,, ,, . . .		307.75	
June 27.	,, ,, ,, ,, . . .		246.00	
July 26.	,, ,, ,, ,, . . .		199.50	
August 23.	,, ,, ,, ,, . . .		177.30	
October 5.	,, ,, ,, ,, . . .		386.15	
November 8.	,, ,, ,, ,, . . .		509.20	
December 8.	,, ,, ,, ,, . . .		266.91	
1905.				
January 4.	,, ,, ,, ,, . . .		501.60	5 238.95
				$8 397.36

January 5, 1905. Examined and found correct.

R. C. P. COGGESHALL,
W. W. ROBERTSON,
Finance Committee N. E. W. W. Asso.

TREASURER,
Water Works Association.

EXPENDITURES.

Bills paid, as per itemized statement		$5 528.21

BALANCE ON HAND.

Deposit People's Savings Bank, Worcester	$1 451.38	
Deposit Mechanics Savings Bank, Reading	1 084.08	
Deposit First National Bank, Reading	333.69	
Total balance		2 869.15
		$8 397.36

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1904.			
February	2.	Samuel Usher, printing December JOURNAL	$417.80
		W. N. Hughes, printing and stamped envelopes	54.50
		Hub Engraving Co., plates	19.71
	12.	Hooper, Lewis Co., blank books	2.81
		Samuel Usher, reprints	42.25
		W. S. Greenough & Co., paper and letter file	2.05
		Miss J. M. Ham, salary for January	35.00
	18.	B. D. Bourne, stereopticon, January meeting	10.00
		W. N. Hughes, cards	1.00
March	7.	Hub Engraving Co., plates	5.45
		Thomas P. Taylor, stereopticon, February meeting	10.00
		W. N. Hughes, printing	16.00
		Miss J. M. Ham, salary for February	35.00
		Boston Society of Civil Engineers, rent to February 29	100.00
		D. Gillies' Sons, printing and stamped envelopes	123.17
	18.	W. N. Hughes, printing	3.75
		Allen, Doane & Co., rubber stamp	.90
		A. Amerena & Peters, music, February and March meetings	20.00
	23.	Charles W. Sherman, salary to April 1	75.00
		Charles W. Sherman, postage and expenses	11.70
		Hub Engraving Co., plates	11.52
April	5.	Robert J. Thomas, advertising agent to April 1	70.30
		Hub Engraving Co., plates	5.32
		Willard Kent, salary to April 1	50.00
		Willard Kent, expenses, guest tickets, etc., February and March meetings	54.20
	9.	Miss J. M. Ham, salary for March	35.00
		Samuel Usher, March JOURNAL and reprints	322.75
	18.	Bacon & Burpee, report of January, February, and March meetings	73.50
	27.	Samuel Usher, printing constitution and list of members	97.50
May	3.	W. N. Hughes, printing	1.00
	11.	D. Gillies' Sons, printing	3.35
		Hub Engraving Co., plates	1.58
	17.	W. N. Hughes, envelopes and printing	39.27
		Miss J. M. Ham, salary for April	35.00
		Miss M. J. Ham, postage, telephone, and messengers	41.20
		Amount carried forward	$1 827.58

	Amount brought forward	$1 827.58
May 25.	Wright & Potter Printing Co., printing	51.00
June 10.	Miss J. M. Ham, salary for May	35.00
	W. N. Hughes, envelopes and printing	24.00
	Samuel Usher, June JOURNAL and reprints	307.48
	Charles W. Sherman, salary to July 1	75.00
	Charles W. Sherman, postage	5.00
27.	John F. Dixon, steamer *King Philip*, June meeting	200.00
	D. O. Wade, dinners at Nantasket Point	96.00
July 5.	Miss J. M. Ham, salary for June	35.00
	A. Amerena & Peters, music at June meeting	14.00
	Willard Kent, salary to July 1	50.00
	Willard Kent, expenses June and September meetings	12.80
19.	R. J. Thomas, advertising agent to July 1	72.70
	Hooper, Lewis & Co., stationery	7.25
August 9.	Library Bureau, card index and printer's copy	40.00
	D. Gillies' Sons, printing	13.75
	Miss J. M. Ham, salary for July	35.00
15.	Samuel Usher, printing index to JOURNAL	273.00
25.	Hub Engraving Co., plates	1.12
31.	Samuel Usher, printing	4.00
September 6.	Miss J. M. Ham, salary for August	35.00
	Miss J. M. Ham, postage and messengers	36.42
30.	Charles W. Sherman, salary to October 1	75.00
	Charles W. Sherman, postage and drafting	13.00
	Whitehead & Hoag Co., badges	36.00
	Thomas P. Taylor, stereopticon, September meeting	35.43
	W. N. Hughes, printing	6.25
October 6.	Samuel Usher, reprints	24.00
	Miss J. M. Ham, salary for September	35.00
	Robert J. Thomas, advertising agent to October 1	60.00
	Willard Kent, salary to October 1	50.00
	Willard Kent, telephones, telegrams, and expenses arranging Holyoke meeting	27.40
12.	Samuel Usher, September JOURNAL	359.31
	Hub Engraving Co., plates	16.54
	D. Gillies' Sons, printing	20.75
24.	Hub Engraving Co., plates	4.77
	Boston Society of Civil Engineers, rent to August 31	200.00
	Amount carried forward	$4 214.55

	Amount brought forward	$4 214.55
	Frank E. Merrill, expenses, Committee of Exhibit	18.13
November 10.	W. N. Hughes, printing	7.00
	Miss J. M. Ham, salary for October	35.00
	Miss J. M. Ham, postage and express	58.82
	Walter Gardner, lantern slides	3.00
	Samuel Usher, printing summary of statistics .	6.50
December 12.	W. N. Hughes, printing	2.00
	Thomas P. Taylor, stereopticon, November meeting	10.00
	Hub Engraving Co., plates	15.72
	Miss J. M. Ham, salary for November	35.00
	Miss J. M. Ham, letter book, postage, and telephones	12.79
	The Engineering News Publishing Co., cuts . .	6.00
	Boston Society of Civil Engineers, rent to November 30	100.00
17.	Charles W. Sherman, salary to December 31 . .	75.00
	Charles W. Sherman, postage	7.60
23.	A. Amerena & Peters, music, November and December meetings	20.00
	Hub Engraving Co., plates	4.50
	Hotel Brunswick, electrical equipment	3.10
	Low's Express, teaming	6.00
24.	Bacon & Burpee, reporting September, November, and December meetings	136.00
	Robert J. Thomas, advertising agent to January 1, 1905	79.75
30.	Samuel Usher, December Journal	391.65
	Willard Kent, salary to December 31	50.00
	Willard Kent, expenses	30.00
January 4.	D. Gillies' Sons, printing.	35.00
	Samuel Usher, reprints	130.00
	Hub Engraving Co., plates	35.10
	Total bills paid	$5 528.21

On motion of Mr. Metcalf, the report was accepted and placed on file.

Mr. Charles W. Sherman, Editor, presented the following report:

Report of the Editor.

Boston, January 11, 1905.

To the New England Water Works Association, — The following is my report as Editor of the Journal, for the year 1904.

The December issue appears so late in the year that it is practically impossible to send out bills for advertising therein and get any returns before the annual meeting. This condition is substantially the same each year, and therefore each year's report includes the advertising returns properly belonging to the December number of the year preceding. The December issue of 1904 contained 27.92 pages of paid advertisements, which if maintained throughout the year would have an annual value of \$1 935. A year ago the Journal contained 25¼ pages of paid advertisements, of an annual value of \$1 750.

The accompanying tables show in detail the amount of material in the Journal, the receipts and expenditures, and a comparison with the four preceding volumes:

TABLE No. 1.

Statement of Material in Volume XVIII, Journal of the New England Water Works Association, 1904.

Number.	Date of Issue.	Number of Pages of: Papers.	Proceedings.	Total Text.	Index, etc.	Advertisements.	Covers and Contents.	Inset Plates.	Total.	Cuts.
1	March	72	34	106	—	30	4	6	146	11
2	June	136	4	140	—	28	4	14	186	7
3	September	84	6	90	—	30	4	12	136	1
4	December	125	30	155	9	30	4	12*	210	7
	Total	417	74	491	9	118	16	44	678	26
	Index to Transactions and Journal								116	
									794	

* Includes 8 plates not yet sent out.

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XVIII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1904.

RECEIPTS.		EXPENDITURES.	
From advertisements	$2 020.56	For printing JOURNAL	$1 407.44
From sale of JOURNALS	94.30	For Index to Transactions and JOURNAL	316.75
From sale of reprints	10.55	For Preparing Illustrations	137.83
From subscriptions	155.25		
	$2 280.66	For Editor's salary	300.00
		For Editor's incidentals	47.00
		For Advertising Agent's commissions	282.75
		For reporting	209.50
		For reprints	221.00
Net cost of JOURNAL	648.11	For statistics forms	6.50
	$2 928.77	Gross cost of JOURNAL and Index	$2 928.77

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV, XV, XVI, XVII, AND XVIII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. xiv.	*4 numbers of Vol. xv.*	*Vol. xvi.*	*Vol. xvii.*	*Vol. xviii.*
Edition (copies)	1 100	1 200	1 200	1 200	900
Average membership	583	586	571	587	596
Pages of text	345	363	403	430	491
Pages of text per 1 000 members	600	618	707	733	824
Total pages, all kinds	485	526	584	619	794
Total pages per 1 000 members	832	913	1 020	1 051	1 332
GROSS COST:					
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77
Per page	4.03	4.10	4.18	4.38	3.69
Per member	3.35	3.75	4.27	4.61	4.91
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18
Per member per 1 000 pp. text	9.71	10.31	10.60	10.72	10.00
NET COST:					
Total	$347.55	$332.90	$622.89	$770.62	$648.11
Per page	.72	.62	1.07	1.25	.82
Per member	.60	.57	1.09	1.31	1.09
Per member per 1 000 pages	1.23	1.06	1.87	2.12	1.30
Per member per 1 000 pp. text	1.73	1.57	2.71	3.05	2.22

The gross cost of the JOURNAL is increasing each year, as is natural since the number of pages is increasing. The net cost, however, is less than last year, being $648.11 against $770.62 for 1903. This result is surprising in

view of the fact that the cost of the "Index to the Transactions and JOURNAL," amounting to $316.75, is included in the cost of the JOURNAL for 1904.

The total cost of the illustrations in the JOURNAL has been $300.83, or 10.3 per cent. of the gross cost of the volume.

The usual fifty reprints of papers have been furnished to their authors without charge. In addition, extra copies of their papers have been given to those Holyoke members who presented papers at the convention, in slight recognition of their energy and foresight which aided so materially in the success of the convention. The net cost to the Association has averaged $7.27 for each paper reprinted.

The present circulation of the JOURNAL is:

Members (all grades)	604
Subscribers	44
Exchanges	19
	667

The former custom of sending out three hundred sample copies of each issue has been discontinued, as it was a considerable expense to the Association with no apparent advantages.

Last year I reported that the net cost to the Association of reprinting the Pipe Specifications for sale was $22.50. This year there have been further receipts from sales amounting to $50.50, with no expenses; consequently the Association has now made a net gain on the specifications of $28.00.

I am glad to report the gradual extension of the use of the summary of statistics. The usual compilation of statistics from such summaries has been made and published in the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN,

Editor.

On motion of Mr. Fuller the report was accepted and placed on file.

The report of the Auditing Committee was submitted by Mr. R. C. P. Coggeshall, as follows:

REPORT OF FINANCE COMMITTEE.

BOSTON, MASS., January 5, 1905.

To the New England Water Works Association, — In accordance with the provision of Article VI, Section 5, of the Constitution of this Association, it is the duty of the "finance committee" to meet on or before the day of the annual meeting and audit the accounts of the Secretary and Treasurer.

We, the undersigned members of the "finance committee" of this Association for the past year, met this day by appointment with your Secretary and Treasurer, at the headquarters of this Association at Tremont Temple, in this city, and have attended to the duty as above described.

We proceeded with the work as follows: We first examined the Secretary's cash book. We verified the additions and found the total receipts as stated therein to be correct and to the amount of \$5 238.95, which amount the Secretary has transmitted to the Treasurer and holds the receipt of the latter therefor. We examined in detail the different accounts in your Secretary's ledger and have verified the Secretary's statement of unsettled accounts which the Secretary presents in his report. This we find amounts to \$825.95 in detail as follows:

Dues of members	\$213.00	
Dues of associates	108.75	
Due from advertisements	483.75	
Due from sundries	30.45	\$835.95

The amount uncollected from advertisements, seemingly large, is due to the fact that bills for same could not be issued until the December issue of the JOURNAL had been delivered. Sufficient time has not since elapsed to make the collection of this account, but with the experience of former years before us, it is safe to predict that practically all the items of this account will be collected within sixty days.

We do not find that your Secretary is in any way responsible for the amount of unpaid dues as shown above. We are presuaded that there has been no lack of diligence upon his part in an effort to collect the same. The trouble may be wholly traced to a defect in the Constitution which allows unpaid dues to collect for more than two years.

An examination of the Treasurer's accounts shows that it agrees with that of the Secretary in the amount received, viz., \$5 238.95. We have checked every item in his entries of disbursements amounting to \$5 528.21 and find each item properly approved and secured by vouchers. We have checked the

Treasurer's statement of balance on hand January 2, 1905, $2 869.15 by examining his bank account.

In conclusion, your committee feel that it is due to your Treasurer, Secretary, and Assistant Secretary for us to here testify to the admirable appearance of the various books which were placed before us for examination, and we feel that the Association is to be congratulated in having its financial affairs in such competent hands.

Respectfully submitted,

R. C. P. COGGESHALL.
W. W. ROBERTSON.

On motion of Mr. Fuller the report was accepted and placed on file.

Election of Officers.

Mr. E. J. Chadbourne submitted the following report of tellers appointed to canvass ballots:

Total number of ballots 210, 4 of which were entirely blank.

For President.

George Bowers, Lowell, Mass. 206

For Vice-Presidents.

James Burnie, Biddeford, Me. 206
Frank A. Andrews, Nashua, N. H. 206
George E. Crowell, Brattleboro, Vt. 206
Frederick W. Gow, Medford, Mass. 206
Edmund W. Kent, Woonsocket, R. I. 206
Charles E. Chandler, Norwich, Conn. 206

For Secretary.

Willard Kent, Narragansett Pier, R. I. 206

For Treasurer.

Lewis M. Bancroft, Reading, Mass. 205

For Editor.

Charles W. Sherman, Boston, Mass. 205

For Advertising Agent.

ROBERT J. THOMAS, Lowell, Mass.	206

For Additional Members of Executive Committee.

FRANK E. MERRILL, Somerville, Mass.	206
GEORGE A. STACY, Marlboro, Mass.	206
JAMES L. TIGHE, Holyoke, Mass.	206

For Finance Committee.

W. W. ROBERTSON, Fall River, Mass.	206
R. C. P. COGGESHALL, New Bedford, Mass.	206
HARRY L. THOMAS, Hingham, Mass.	206

The report of the tellers was accepted, and the officers were declared duly elected. President Brooks, in calling the newly elected President to the chair, said:

I will now resign to you, Mr. Bowers, the chair, hoping that your administration may be as pleasant and in every way as satisfactory as you could wish. (Applause.)

PRESIDENT BOWERS. Gentlemen, I thank you for the honor you have conferred upon me in electing me President of the Association, and I promise you that I will faithfully carry forward the work and do all I can to assist you in keeping the standing of this Association as high as it has ever been before. (Applause.)

We have with us to-day one whom we all love to hear, and it gives me great pleasure to present to you our former President, now an honorary member of this Association, Desmond FitzGerald. (Applause.)

Mr. Desmond FitzGerald then spoke on the Manila Water Supply and Life in the Philippines, illustrated by lantern views.

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, Mass., February 8, 1905.

George Bowers, President, in the chair.

The following members and guests were in attendance:

Members.

S. A. Agnew, E. Atkinson, C. H. Baldwin, L. M. Bancroft, George Bowers, D. Brackett, E. C. Brooks, F. H. Carter, G. F. Chace, J. C. Chase, S. K. Clapp, F. C. Coffin, M. F. Collins, R. J. Crowley, H. D. Eaton, H. P. Eddy, C. H. Eglee, August Fels, C. R. Felton, F. L. Fuller, J. C. Gilbert, A. S. Glover, F. W. Gow, F. E. Hall, J. O. Hall, T. G. Hazard, Jr., L. M. Hastings, V. C. Hastings, H. G. Holden, C. G. Hyde, H. R. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. Kimball, G. A. King, C. F. Knowlton, H. V. Macksey, W. E. Maybury, F. E. Merrill, H. E. Perry, E. B. Phelps, W. W. Robertson, J. W. Smith, S. Smith, G. H. Snell, E. G. Smith, J. T. Stevens, W. F. Sullivan, T. V. Sullivan, R. J. Thomas, H. L. Thomas, W. H. Thomas, L. D. Thorpe, J. L. Tighe, D. N. Tower, W. H. Vaughn, C. K. Walker, W. J. Wetherbee, G. C. Whipple, F. B. Wilkins, C.-E. A. Winslow, G. E. Winslow. — 63.

Associates.

Ashton Valve Co., by C. W. Houghton; Chapman Valve Mfg. Co., by Edw. F. Hughes; Henry A. Desper; Hart Packing Co., by Horace Hart; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, F. A. Smith and H. D. Winton; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by W. L. Dickel; National Lead Co., by G. L. Whittemore; National Meter Co., by Chas. H. Baldwin and J. G. Lufkin; Pittsburg Meter Co., by H. F. Peck; Rensselaer Mfg. Co., by C. L. Brown; The Platt Iron Works Co., by F. H. Hayes; A. P. Smith Mfg. Co., by F. N. Whitcomb; Sumner & Goodwin Co., by H. A. Gorham; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. E. Hall and W. F. Hogan; Builders Iron Foundry, by F. N. Connet. — 24.

Guests.

W. H. Van Winkle, New York City; F. L. Weaver, water commissioner, Lowell, Mass.; J. F. Stark, president water board, Nashua, N. H.; F. A. Snow, S. C. Prescott, bacteriologist, and H. S. Brown, Boston, Mass.; W. E. Lothrop, Leominster, Mass.; Theodore Moorehead, Chinese Government Service, Shanghai, China. — 8.

(Names counted twice. — 3.)

The following were elected members:

Resident. — John Doyle, Worcester, Mass., general foreman, Worcester Water Department; Charles L. Wooding, Bristol, Conn., manager Bristol Water Company; Elbert W. Gaylord, Bristol, Conn., superintendent Bristol Water Company.

Non-Resident. — John S. Cook, Passaic, N. J., hydraulic engineer, Paterson, N. J.; J. H. Van Keuren, Jersey City, N. J., chief engineer, Jersey Water Company; Dr. T. B. Hunter, Monterey, Cal., resident engineer, Monterey Water Works.

Associate. — Roy S. Barker, Providence, R. I., contractor for well boring and test borings.

The President announced that the Executive Committee had voted to hold the next annual convention in New York City.

The first paper of the afternoon, entitled "The Maine Water District and Appraisals," was by Harvey D. Eaton of Waterville, Me. The paper was discussed by Mr. Frank L. Fuller of Boston, ex-Mayor John O. Hall of Quincy, Mr. Freeman C. Coffin of Boston, Mr. August Fels of Lowell, Mr. George A. King of Taunton, Mr. Edward Atkinson of Boston, and Prof. E. G. Smith of Beloit College, Beloit, Wis.

The next paper was on "The Kennebec Valley Typhoid Fever Epidemic of 1902–3." This was illustrated by diagrams and maps, and was prepared by Mr. George C. Whipple and Dr. E. C. Levy, the paper being read by Mr. Whipple. The discussion was participated in by Mr. Charles G. Hyde of Harrisburg, Pa., engineer on construction of filter plant, Mr. Charles-Edward A. Winslow, instructor in biology at the Massachusetts Institute of Technology, Boston, and Mr. Edward Atkinson of Boston.

Adjourned.

EXECUTIVE COMMITTEE.

TREMONT TEMPLE,
WEDNESDAY, December 14, 1904.

There was a meeting of the Executive Committee of the New England Water Works Association to-day and the following were present: President Edwin C. Brooks, V. C. Hastings, George E. Crowell, Frank E. Merrill, George A. Stacy, H. G. Holden, Willard Kent, L. M. Bancroft, Charles W. Sherman, and Robert J. Thomas.

Application of George E. Gilchrist & Co., for associate membership received and recommended.

Letter from William B. Bryan, chief engineer, Metropolitan Water Board, London, England, acknowledging election to honorary membership received and read.

Mr. Stacy, of the Subject Committee, reports that it is the unanimous opinion of that committee that the ladies should be invited to attend some one of the winter meetings of the Association. After discussion, on motion of Mr. Thomas, it was voted: That the January meeting be Ladies' Day, and that the Subject Committee be a committee with full powers to make all necessary arrangements therefor.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association, January 11, 1905, at headquarters, Tremont Temple, at 11.30 A.M.

Present: President Edwin C. Brooks, and H. G. Holden, Charles W. Sherman, L. M. Bancroft, Frank E. Merrill, J. C. Hammond, Jr., Robert J. Thomas, and Willard Kent.

Letter from Mr. F. W. Dean was read declining re-election as member and chairman of Subject Committee.

Letter from Mr. R. C. P. Coggeshall with reference to change of By-Laws in relation to payment of dues was read and referred to Executive Committee of ensuing year.

The following applications for membership were received, and it was voted to recommend the election of the applicants to membership in the Association:

Mr. Charles T. Main, mechanical engineer, 53 State Street, Boston, Mass.; Henry J. Williams, chemical engineer, 161 Tremont Street, Boston, Mass.; Richard K. Hale, sanitary engineer, Chestnut Hill Avenue, Brookline, Mass.; W. W. Berry, superintendent Centerville Water Works, Centerville, Iowa.

The President named Messrs. D. N. Tower and J. W. Crawford as tellers of election of officers for ensuing year.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of Executive Committee of the New England Water Works Association February 8, 1905, at headquarters, Tremont Temple, at 11.30 o'clock A.M.

Present: President George Bowers and members Frank E. Merrill, James L. Tighe, Robert J. Thomas, L. M. Bancroft, and Willard Kent.

On motion of Mr. Thomas, seconded by Mr. Tighe, it was voted: That the next annual convention of the New England Water Works Association be held in the month of September in the city of New York, and that the President be authorized to appoint a committee of three to make the necessary arrangements therefor.

At the suggestion of the President it was voted: That Mr. Merrill be and hereby is made a committee to make necessary arrangements for transportation.

Following the suggestion of the Finance Committee, and others, on motion of Mr. Thomas, seconded by Mr. Merrill, it was voted: That the Executive Committee recommend the following changes in the Constitution of the New England Water Works Association to be acted upon at the March meeting by the members of the Association, viz.:

That Section 1 of Article III be amended by the addition of the following clause: "All applications for membership presented to the Association for action must be accompanied by the proper initiation fee and dues for whole, or fractional part, of current year in which application is presented."

That Section 5 of Article III be amended to read: "The annual membership dues shall be payable in advance on the date of the annual meeting in January. At the expiration of ten months after the annual meeting, the Secretary shall notify each member who has not paid his dues for the current year, that unless the same are paid within thirty days, his membership in the Association shall cease; and if said dues are not paid within said period, the Secretary shall drop the name of said member from the membership roll. The Executive Committee may, however, at its discretion reinstate said person on the payment of all arrears."

That Section 4 of Article VI be amended by the addition of the following clause: "He shall deposit all funds received in such place of deposit as may be approved by the Executive Committee. All orders for withdrawal of funds and checks for disbursements shall be signed by the Treasurer and countersigned by the President."

The following-named applications for membership were received, and it was voted to recommend the same to the Association for election to membership:

As Members. — Charles L. Wooding, manager Bristol Water Company, Bristol, Conn.; Elbert W. Gaylord, superintendent Bristol Water Company, Bristol, Conn.; John Doyle, general foreman Water Department, Worcester, Mass.; T. B. Hunter, resident engineer Pacific Improvement Company's Water Works, Monterey, Monterey County, Cal.; John H. Cook, hydraulic engineer S. U. M., Paterson, N. J.; Charles A. Van Keuren, chief engineer, Jersey City, N. J.

As Associate. — Roy S. Barker, driven wells, Providence, R. I.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Henry A. Cook, superintendent of the Salem Water Department, died January 10, 1905. He was born in San Francisco, January 11, 1858, and was educated at Salem, where he came in 1864. He graduated at the Salem High School in 1876 and later studied at the Institute of Technology, and was in the office of Ernest W. Bowditch, civil engineer, of Boston. He opened an office in Salem in 1889 and was employed as an engineer on the Salem Water Works, laying the new main from the pumping station in North Beverly through Danvers to Salem. In the fall of 1891 he was elected superintendent of the Salem Water Works, which position he had since held. He leaves a widow, a daughter of Judge J. B. F. Osgood of Salem. Mr. Cook was elected a member of the New England Water Works Association on February 10, 1902.

J. A. Marion died at his home in Montreal, Canada, on December 2, 1904.

Mr. Marion was born at St. Simon, County of Bagot, March 31, 1871.

He was a student of the Jacques-Cartier Normal School at Montreal, from which he graduated with the Gold Medal of The Prince of Wales. He then entered the Polytechnic School and at the age of twenty he was received Engineer, with great distinction.

In 1897 he married Miss Maria Berthiaume of St. Hugues, who survives him, as also two daughters, aged six and two years.

Mr. Marion, after graduating as Engineer, spent some time in the United States. Returning to Montreal he, in 1892, opened a Patent Soliciting Office under the firm name of Marion & Marion, with a branch office at Washington, D. C.

Mr. Marion was a member of a large number of societies of engineers. He was a Bachelor of Applied Science, Laval University, member of the Canadian Society of Civil Engineers, of

the "Association des Ingénieurs Conseils en matière de propriété Industrielle" (France), of the "Chambre Syndicale des Conseils en matière de propriété industrielle" (Belgique), of the American Water Works Association, etc.

He was elected a member of the New England Water Works Association on December 13, 1893.

John P. K. Otis, president of the Union Water Meter Company, an Associate of the New England Water Works Association, died at his home in Worcester, Mass., at 1.30 o'clock Saturday morning, December 31, 1904.

John Pierce Kettell Otis was born in Worcester, March 9, 1853, and was the son of John C. and Mary E. (Kettell) Otis.

He obtained his education at the grammar and high schools in Worcester, and then began the study of engineering, which became his life's work. In 1869 he entered the City Engineer's office in Worcester, and in 1871 attended a course at the Worcester Polytechnic Institute, from which he was graduated two years later.

Mr. Otis was then appointed assistant engineer for the construction of the Springfield Water Works, and after two years there was, in 1875, appointed engineer for the construction of the Portland, Me., Water Works, a position he held until 1878. From 1878 to 1881 he was instructor of civil engineering in Worcester Polytechnic Institute. In 1880 in connection with his duties as instructor in Worcester Polytechnic Institute he assumed the position of manager of the Union Water Meter Company, of Worcester, and in 1900 was also made its president.

He was a member of the Montacute Lodge, A. F. & A. M., Worcester Royal Arch Chapter, Worcester Board of Trade, Worcester Society of Engineers, Society of Antiquity, Commonwealth Club of Worcester and Worcester Mechanics Association.

Records of the Union Water Meter Company contain the following entry, viz.:

"The Board of Directors of the Union Water Meter Company, in meeting assembled this twenty-eighth day of January, 1905, desiring to place on record expression of their appreciation of the upright manliness, strict integrity, and ever painstaking serv-

ices characteristic of their late President, John Pierce Kettell Otis, whose death occurred December 31, 1904.

"Resolved that by his death this Corporation has lost a valuable officer and each individual member a friend of whose friendship he can always think with feelings of deepest thankfulness."

Macy Stanton Pope was born at East Machias, Washington County, Me., on July 26, 1869, of sturdy New England parentage, his father, James Otis Pope, and his mother, Olive Chase, both being natives of East Machias.

His early training was obtained in the public schools of East Machias, and in Washington Academy, located in his native town, from which he graduated in 1888.

Brought up in a community chiefly interested in lumber and shipping, he spent much of his time in his father's mill and in the woods, of which his father owned large tracts. He thus acquired not only an intimate knowledge of these industries and a deep interest in them, but habits of close observation and independent thought, which marked his later life and work.

In the fall of 1888 he entered the Massachusetts Institute of Technology and graduated from the department of civil engineering in 1892.

He then entered the employ of the Associated Factory Mutual Fire Insurance Companies of Boston, taking part in a series of tests upon cast-iron water pipe and fittings being conducted at Nashua, N. H., by Mr. John R. Freeman.

In the following fall he was called to the Massachusetts Institute of Technology as assistant to Professor Dwight Porter in the department of hydraulics, but resigned his position at the end of the academic year to take up practical work again and to re-enter the employ of the Factory Mutual Company.

Here his time was divided between the testing department, in which he made tests of various fire protection and prevention devices, the inspection department in which he visited mills in different parts of the country and made plans of and reported upon them, and in the private work of Mr. John R. Freeman, then engaged in addition to his regular duties as engineer to the Factory

Mutual Company, in preparing plans for the improvement of the Pennichuck Water Works at Nashua, N. H., and of the power plant of the Piscataquis Pulp and Paper Company, and in various other kindred projects.

In February, 1898, Mr. Pope obtained leave of absence from his company to devote himself to the lumber interests of his family estate. Later, after making a somewhat extended tour through the southern and western states with his mother, he resumed his active connection with the company in June, 1900.

From this time his work lay principally in the inspection department of the company; first in routine inspection work, later in special inspections. His early training and natural traits, combined with his personal experience with the practical affairs of business, stood him in good stead and made him a most valuable man for the department. Clear headed, well balanced, and judicially minded, he was well fitted to do the work which fell to him, and merited the words of commendation of one of his associates, who wrote after Mr. Pope's death:

"It is the verdict of all that the work done in each of these various fields was well done, and that the results were received by those who used them with the fullest confidence. In every case strong common sense and a clear appreciation of relative values were predominating characteristics."

Mr. Pope was much interested in engineering matters and was a member of various engineering societies — amongst them the American Society of Civil Engineers (in which he was an associate member), The Boston Society of Civil Engineers, The New England Water Works Association, The Society of Arts, and of the Technology and Appalachian Mountain Clubs.

He was devoted to his old home and took a warm and active interest in its affairs, as was shown by his presenting to the town of East Machias, jointly with his brothers, John A. and Warren F. Pope, a new bridge across the East Machias River. This structure, a fine three-span, re-enforced, concrete masonry arch, was built to replace a dangerous old timber crib bridge, not only as a memorial to the Pope family, which had been prominently identified with the affairs of the town for a century, but as an object lesson to the community.

His Alma Mater and the Washington Academy, of which he was a trustee, also claimed Mr. Pope's interest, and were substantially remembered by bequests in his will.

Last summer Mr. Pope took the opportunity to travel abroad for some months for rest and recreation, but shortly after his return serious symptoms developed and he died of acute Bright's disease at Brookline, Mass., on December 10, 1904.

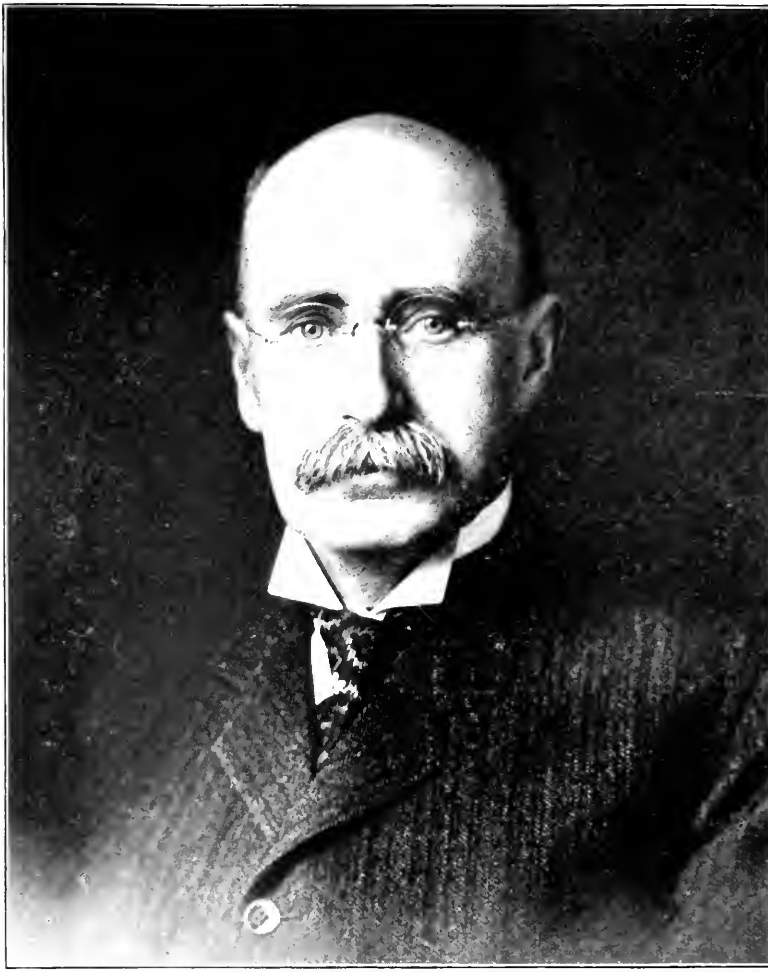
Quiet and reserved to the world, but a warm and loyal friend, simple in tastes, with high ideals, a well balanced and indomitable worker, Macy Stanton Pope will long be remembered by his friends as a good example of a fine and virile type of New Englander.

He was elected a member of this Association on March 13, 1901.

BOOK NOTICE.

"Water and Public Health." By James H. Fuertes. 12 mo. 75 pages. John Wiley & Sons, New York. Price, $1.00.

This little book discusses in an interesting manner the relations between the character of the water supplies in some seventy-five cities and the typhoid fever death-rates for the years 1890–1895 inclusive. It is profusely illustrated by diagrams. Typhoid fever is the only water-borne disease considered, and no reference is made to other means of dissemination of this disease.



GEORGE BOWERS

President New England Water Works Association

1905

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XIX. June, 1905. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE MAINE WATER DISTRICTS AND APPRAISALS.

BY HARVEY D. EATON, WATERVILLE, ME.

[*Read February 8, 1905.*]

I hardly need say, for this audience will speedily discover it for themselves, that I am not a practical water-works man.

My regular calling is the law. But problems connected with water works have engaged my attention almost constantly for nearly ten years, and this Association has done me the honor to admit me to its membership.

I fully realize that discussions of municipal ownership are nearly twenty years behind the times, but, while I yield to no one in pride in my native state, I am obliged to confess that it is only recently that municipal ownership became generally practicable in our state.

More than thirty years ago excessive indulgence in municipal aid to railroad enterprises led to the adoption of a constitutional debt limit of five per cent., with no exceptions in favor of water debts. At that time there were few water plants in the state, and as others came to be installed by private parties the owners found this municipal debt limit a safe barrier against disturbance of their investments. The leading water-works owners were also leading railroad men, and as our principal railroads are part and parcel of the Boston & Maine system, the whole combination of railroad lawyers and lobbyists of Maine and Massachusetts was constantly arrayed against all efforts at municipal ownership.

At one time, ten or twelve years ago, a noteworthy attempt was made to change the constitution so that water debts would be excepted from its operation. The owners of water systems, through their friends and agents, worked up a perfect scare among the saving banks of the state, each one of which held a few water company bonds, so that they remonstrated and protested with the utmost vigor against the change, and the legislature was induced not to submit the matter to the people at all. The attempt has never been renewed, and our debt limit still remains unchanged.

Living in Waterville, my interest was engaged in local conditions in 1895. Two or three years of otherwise fruitless contention over minor matters revealed to the community that we were paying exorbitant rates for wretched water service. Besides our own city, three adjoining villages were supplied from the same station and reservoir, making a very remunerative plant for the owners, while the water was taken from a small stream which served as the outlet for the sewers of another village only five miles away. This same stream also furnished power for pumping. Spring water wagons made daily rounds and the expense of water from that source in many families equaled the amount paid the public water company. The fact that within a radius of ten miles were eight splendid ponds only added to the aggravation. The owners of the plant lived at a distance, and the returns made them satisfied.

Our own city's debt was at the limit, and the proposition was too large for the other places. After wasting months of study on impracticable plans, it occurred to me that if all the places served should unite to form a new municipality for water purposes only, it would not be subject to the debt limit which by the language of the constitution applied expressly to cities and towns. Months more were spent in drafting and revising a bill to embody this idea, and in March, 1898, I submitted it to my former instructor in constitutional law, Prof. James B. Thayer, of the Harvard Law School. In a very kind note he stated his belief that the plan was legal and encouraged me to present it to the public.

The rest of that year was spent in holding meetings and conferences in the four places. Finally, only one place, the Fair-

field Village Corporation, decided to join with our city in asking for the proposed legislation.

The bill was introduced in January, 1899, and passed with no opposition.* In fact, up to this time the water company had seemed to regard the whole matter as a harmless vagary. It was provided that the act should not take effect unless approved by a popular vote in each of the places composing the district. Apparently the company assumed that the bill would fail of popular approval, but it was ratified by overwhelming votes in each place.

Proceedings under the act were begun at once, and then we learned that the day of gentle tolerance was past. The list of counsel who appeared against that process included about all the distinguished corporation attorneys in the state. Every pretext for delay, and every objection that human ingenuity could devise, were interposed. At length the various questions as to the legality of the act, and the right to proceed under it, were argued before the full bench in Portland on successive days in August, 1900.

In March, 1902, the court published its opinion, which was lengthy and sweeping. The act was completely sustained. Its constitutionality and the legality of all its provisions were upheld. And thus there came into operation in the state of Maine a practical plan of municipal ownership where formerly the private corporation had held almost unbroken sway. Bangor and Lewiston, to be sure, already had city ownership of their water plants, but they began many years ago, and the other cities and towns found it impossible to follow their lead on account of the debt limit.

The Kennebec Water District, the pioneer, included Waterville and Fairfield, but was also authorized to serve the two adjoining towns of Benton and Winslow, being the territory already served by the Maine Water Company.

The plan has been adopted at Dover and Foxcroft, Augusta, Gardiner, and Brunswick, while many other places are watching its operations and discussing the subject of its adoption for themselves.

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* The act is abstracted in Appendix I.

The plan is nothing more than the organization of the desired territory and people into a new, distinct, and separate municipality for water purposes only, leaving all other forms of municipal government to pursue their accustomed functions precisely as though the district had not been organized.

The whole charter contains only sixteen brief sections covering about six octavo pages.

The act provided that the district might acquire by exercise of the right of eminent domain "the entire plant, property, and franchises, rights, and privileges" held by the water company within the district and the two adjoining towns, and that the court should appoint a board of three appraisers to "fix the valuation of said plant, property, and franchises at what they are fairly and equitably worth, so that said Maine Water Company shall receive just compensation for all the same."

This provision made a radical distinction between our appraisal and those with which the country has generally become familiar, in that it allowed the appraisal of the franchise.

The inclusion of the franchise with the property to be appraised is the rule, but the exceptions are much more numerous than the cases where the rule is followed.

For instance, in the Kansas City case, which is one of the best-known authorities in this country, it was expressly provided by contract before the works were built that after a certain time they should pass to the city at an appraisal *excluding* the franchise or value arising from future earning capacity. The cases of that class are quite numerous and, of course, there can be no just complaint at the omission of the franchise from the valuation.

In Massachusetts we have another class of cases, of which that at Newburyport is the leading example, where the legislature grants a municipality the right to build a competing system, unless the water company will sell out at a valuation which excludes the franchise.

This procedure is legal, and, theoretically, it is just and fair because as explained by the Federal Circuit Court "it may well be presumed that when a franchise is obtained which is not exclusive, it is taken with the knowledge and risk that the legislature

is not precluded from granting at any moment a similar and competing franchise."

Practically these last-named cases arouse the most bitter controversy, and it is probably true that the builders seldom realized the full meaning of the doctrine that a competing franchise might be granted at any time.

The Waterville case, however, fell in neither of these classes, but was a plain case of appraisal of all the property and franchises.

Our act contained one provision in regard to appraisal that was unique, and proved highly important. It was the following:

"Before a commission is issued to the appraisers, either party may ask for instructions to the appraisers, and all questions of law arising upon said requests for instructions . . . may be reported to the law court for determination before the appraisers proceed to fix the valuation of the property."

Under this provision, after the determination by the court that the district was legally constituted, each party presented numerous and comprehensive requests for instructions, covering every phase of the appraisal that could be foreseen. The court made some caustic remarks about the anomalous character of this procedure, and then considered all the requests of both parties in an opinion which has already taken rank as one of the most important and exhaustive discussions of the general subject of appraisal that has ever been delivered by any court in the world.

That opinion was received December 27, 1902, and on the 6th of October, 1903, the hearing on appraisal began at Waterville before a board agreed on by the parties, and commissioned by the court, consisting of Hon. Frederick A. Powers, a justice of the Supreme Court; Hon. Frederick H. Appleton, a prominent attorney; and Percy M. Blake, Esq., a civil and hydraulic engineer. Careful preparation had been made by both parties, and the hearing proceeded continuously, two sessions a day being held, until the close on October 30. Within a few days afterward the appraisers made their award, fixing the value at $503 437.75.

The award was large, but that was expected, and the district at once accepted it without formal objection of any kind. The amount of the award was subsequently paid over, and thus terminated the long contest in which not only had municipal owner-

ship been accomplished for our own community, but a principle had been established through which the same thing could be accomplished by any community in the state desirous of doing so.

And, of course, you can understand that this has meant very much to me personally. The years of contest with the brightest minds in New England over the legal questions involved was splendid professional training.

And to sit at the feet of such men as William R. Hill, John R. Freeman, Freeman C. Coffin, George C. Whipple, and John W. Alvord, not to mention such younger men as Dr. E. C. Levy and Leonard Metcalf, and study and discuss with them the problems of hydraulics and health, of engineering and construction, of finance and public policy, was a liberal education in itself. And then to be concerned in taking over the works, and have a hand in their operation and management, in the construction of a new supply system, and the reconstruction of the distribution system has still further impressed me with the importance, yes, the true greatness, of this subject to which you gentlemen are devoting your lives.

APPENDIX I.

An Act to Incorporate the Kennebec Water District (Abstract).

The Act is Chapter 200 of the Private and Special Laws of Maine for 1899.

Section 1 is as follows:

"The territory and people constituting the city of Waterville and the Fairfield Village Corporation shall constitute a body politic and corporate, under the name of the Kennebec Water District, for the purpose of supplying the inhabitants of said district and of the towns of Benton and Winslow and all said municipalities with pure water for domestic and municipal purposes."

Sections 2, 3, and 4 confer power to take and distribute water, lay pipe, etc.

Section 5 provides for organization, election of officers, etc.

Sections 6, 7, 8, and 9 give the right to condemn the old company's plant, and provide for judicial appraisal thereof by bill in equity in the Supreme Court.

Section 10 grants authority to issue bonds.

Section 11 provides that water rates shall be uniform, and so established as to provide revenue for current expenses, maintenance, extensions, renewals, interest, and sinking fund.

Section 12 exempts the district's property from taxation.

Section 13 grants all necessary incidental powers, rights, and privileges.

Sections 14, 15, and 16 cover minor details.

An amendment passed in 1905 broadens the financial powers of the district, and provides more specifically for the appraisal of damages in cases where land has been taken or pipes laid.

Separate acts in Maine and Massachusetts have modified the general laws of those states so as to include water district obligations in the list of investments eligible for savings banks.

APPENDIX II.

The first decision of the court, dated March 3, 1902 (96 Me. 234; 52 Atl. Rep. 774), deals with five leading propositions of the defense.

The first asserts the right of the people to take the property and franchises of a corporation already engaged in public service.

This proposition had already been well established by many decisions, several of them being by the United States Supreme Court, but it was stubbornly fought over in this case.

The second and third decide that it is constitutional to have the value of the water company's property fixed by a board of appraisers or commissioners without having it passed upon by a jury, although the act further provides that in settling ordinary claims for damages by reason of laying pipe across private land, etc., the damages shall be assessed by a jury, and that the establishment of these two different modes of assessing damages under the act is not a denial to the water company of "the equal protection of the laws."

The fourth contention was that the taking of the water company's property would result in the impairment of its contracts for supplying water to the various municipalities served. This objection was probably not much relied on, and the court made short work of it, saying, "A contract is property and, like any other property, may be taken under condemnation proceedings for public use."

The fifth and most important proposition dealt with the debt limit. It was admitted that the city of Waterville, a large part of the district, was already in debt to its limit. But the court held that the constitutional limitation by its express language applied only to "cities and towns," and that it was within the province of the legislature to establish other municipal corporations comprising territory already organized into cities and towns, and that these new municipalities would not be governed by the debt limitation nor their powers affected by the fact that the cities and towns of which they were composed were already in debt to the limit. In other words, the new corporation is an entirely free and independent municipality. This is in accordance with established principles of constitutional interpretation, but the application of these principles to our situation in Maine had not before been made.

APPENDIX III.

Kennebec Water District *v.* City of Waterville, and others. Kennebec. Opinion, December 27, 1902.*

* 97 Me. 185; 54 Atl. Rep. 6; 60 L. R. A. 856.

(*Head Notes by the Court.*)

An act incorporating the plaintiff district authorized it to acquire, by the exercise of the right of eminent domain, "the entire plant, property, and franchises, rights, and privileges now held by the Maine Water Company within said district and the towns of Benton and Winslow." The act further provides that appraisers appointed by the court "shall, upon hearing, fix the valuation of said plant, property, and franchises at what they are fairly and equitably worth, so that said Maine Water Company shall receive just compensation for all the same," but that "before a commission is issued to the appraisers, either party may ask for instructions to the appraisers." Both parties having asked for instructions, and the questions of law arising thereon having been reported to the law court, the court is of opinion that the appraisers should be instructed in accordance with the following principles:

1. The plaintiff, if it takes anything, must take all the property held by the Maine Water Company in the Kennebec Water District, and in Benton and Winslow, whether specifically named in the act or not. This includes the real estate or other property, if any, not connected with the water system, it includes the plant or physical system, and it includes all franchises, rights, and privileges held by the water company, exercised or capable of being exercised.

2. The Maine Water Company is a quasi-public or public service corporation, and is entitled to charge reasonable rates for its services, and no more.

3. The basis of all calculations as to the reasonableness of rates to be charged by a public service corporation is the fair value of the property used by it for the convenience of the public.

4. At the same time, the public have the right to demand that the rates shall be no higher than the services are worth to them, not in the aggregate, but as individuals.

5. Summarized, these elemental principles are, the right of the company to derive a fair income based upon the fair value of the property at the time it is being used for the public, taking into account the cost of maintenance or depreciation and current operating expenses, and the right of the public to have no more exacted than the services in themselves are worth.

6. The reasonableness of the rate may also be affected, for a time, by the degree of hazard to which the original enterprise was naturally subjected; that is, such hazard only as may have been justly contemplated by those who made the original investment, but not unforeseen or emergent risks. And such allowance may be made as is demanded by an ample and fair public policy. If allowance be sought on account of this element, it would be permissible at the same time to inquire to what extent the company has already received income at rates in excess of what would otherwise be reasonable, and thus has already received compensation for this hazard.

7. The franchises granted to the Waterville Water Company by Chapter 141, Private and Special Laws of 1881, as amended by Chapter 59, Private and Special Laws of 1887, and Chapter 14, Private and Special Laws of 1891,

and to the Maine Water Company by Chapter 352, Private and Special Laws of 1893, are not exclusive. Neither are they perpetual and irrevocable. They are subject to legislative repeal. In fixing the value of the franchises, both of these considerations are entitled to their just weight. If the business of the company is now practically exclusive, in that it has no competitor, that fact also may and should be considered by the appraisers when they fix the value of the property of the company as a going concern.

8. In determining the present value of the company's plant, the actual construction cost thereof, with proper allowances for depreciation, is legal and competent evidence, but it is not conclusive, nor controlling.

9. The request that "under no circumstances can the value of the plant be held to exceed the cost of producing at the present time a plant of equal capacity and modern design" should not be given. Among other things, it leaves out of account the fact that it is the plant of a going concern, and seeks to substitute one of the elements of value for the measure of value itself.

10. The actual rates which may have been charged heretofore, and the actual earnings are both admissible and material in determining the value of the plant. The value of the evidence, however, will depend upon whether the appraisers shall find that the rates charged have been reasonable.

11. The quality of water furnished and of the service rendered, and the fitness of the plant and of the source of water supply to meet reasonable requirements in the present and future are material upon the question of present value.

12. The appraisers should regard the franchises of the company as entitling it to continue business as a going concern, but subject to all proper legal duties governing public service companies.

13. Faithfulness or unfaithfulness shown by the water company in the past in the performance of public duty to furnish pure water at reasonable rates is not a proper matter for consideration. It is the franchise as it now exists which is to be taken and paid for.

14. The liability of the company to legal forfeiture of its franchises on account of past unfaithfulness and misbehavior is not to be considered.

15. If the water company and its predecessors have actually received more than reasonable rates hitherto, the excess cannot be deducted from the amount to which the company would otherwise be entitled.

16. No compensation can be allowed to the Maine Water Company for incidental damages to its other property having no physical connection with or contiguity to that taken, and having no relations with it except those which grow out of common ownership, nor for the impairment of the economy and efficiency of administration which are obtained by the combination of many water systems under one management.

17. The real estate or other outside property not directly connected with the water system should be appraised at its fair market value, not at forced sale, but at what it is fairly worth to the seller, under considerations permitting a prudent and beneficial sale thereof.

18. The appraisers may properly consider what the existing system can be reproduced for. But the cost of reproduction will not be conclusive. It will be evidence having some tendency to prove present value. The inquiry along the line of reproduction should be limited to the replacing of the present system by one substantially like it.

19. In estimating even the structure value of the plant, allowance should be made for the fact, if proved, that the company's water system is a going concern with a profitable business established, and with a present income assured and now being earned.

20. So far as the water system is practically exclusive, the element of good-will should not be considered.

21. In fixing structure value, while considering the fact that the system is a going concern, the appraisers should also consider, among other things, the present efficiency of the system, the length of time necessary to construct the same *de novo*, and the time and cost needed after construction to develop such new system to the level of the present one in respect to business and income, and the added net income and profits, if any, which by its acquirement would accrue to a purchaser during the time required for such new construction, and for such development of business and income. But these are to be considered "among other things." They are not controlling. Their weight and value must depend upon the varying circumstances of each particular case.

22. In addition to structure-values, the appraisers should allow just compensation for all the franchises, rights, and privileges to be taken.

23. The value of the franchise depends upon its net earning power, present and prospective, developed and capable of development, at reasonable rates; and the value to be assessed is the value to the seller, and not to the buyer.

24. In considering prospective development of the use of a franchise, consideration must also be had of the fact that further investment may be necessary to develop the use, and of the further fact that at any stage of development the owner of the franchise will be entitled to charge only reasonable rates under the conditions then existing.

25. Subject to all the foregoing limitations, the owner is entitled to any appreciation due to natural causes.

26. The fact that the franchises are to be taken in no respect impairs their value for the purposes of appraisal.

27. The property to be taken, both plant and franchises are to be appraised having in view their value as property in itself and their value as a source of income. There are these elements of value, but only one value of one entire property is to be appraised in the end. These elements necessarily shade into each other.

28. The capitalization of income even at reasonable rates cannot be adopted as a sufficient or satisfactory test of present value. But while not a test, present and probable future earnings at reasonable rates are properly to be considered in determining the present value of the system.

29. The appraisers should be instructed to receive and consider all evidence offered, so far as admissible under the general rules of law, which is pertinent under the rules stated in the requests of the parties, so far as they have been approved, and as limited or explained, in the opinion of the court. See S. C. 96 Maine, 234.

DISCUSSION.

Mr. J. O. Hall. I should like to ask how that $503 000 was provided for. Was it all furnished by Waterville and then divided; and if so, in what way?

Mr. Eaton. The city of Waterville and the Fairfield Village Corporation make a new municipality, and that municipality, with an independent organization for water purposes only, raised the money by its own operations. The money was all procured here in Boston, on the district's obligations.

I might say that in considering the subject since the establishment of the district, one needs to drop " Waterville " and " Fairfield "; the Kennebec Water District is its name for all of these questions.

Mr. Hall. What effect have all these things had on the rate of taxation in Waterville?

Mr. Eaton. Not any effect whatever. The expenses of the district are paid from the water rates or the issue of bonds. There is no connection whatever between the district's organization and the cities or towns composing the district, except that in case we have a surplus, — which we hope will happen some day, but which has not occurred yet, — that surplus is to be returned to the cities and towns composing the district, in the proportions in which they contributed to the revenue.

Mr. Freeman C. Coffin. I have been very much interested in this paper of Mr. Eaton's, and I was very much interested in the proceedings which led to placing the value on these works. You all see how young a man Mr. Eaton is, or looks to be, and yet I first heard of him as " the father of the Maine Water District Bill." (Laughter.)

We find some differences between what might be called the feeling or the sentiment in Maine towards these questions and that in Massachusetts. I think that a water-works system in Maine is regarded more as a strictly private business than in

Massachusetts. It seems to be the feeling there that these companies own their works as they would own a large department store, without regard to the public interest. And if the water works are taken away from them, they look upon it as the taking away of a business which belonged to them just as strictly as if it had been what we consider a private business in which public interests had no place.

As I look at the matter, I certainly agree with Mr. Eaton in his suggestion that there is a franchise value, or whatever you please to call it; there is a certain value in a water-works system for which the company is entitled to receive compensation. On the other hand, when a company is given the right by the legislature to take a water supply — and they always try to take the best to be obtained, and the one that can be the most economically developed — certainly they are given something that is on broad principles the property of the public, they are given something in which the public has rights. When a company is given the right to supply the public with water, it is, I believe, upon the theory that it is first for the convenience and benefit of the public, and, secondly, to enable it to make a reasonable profit for itself. It certainly should have a reasonable profit. I have no sympathy whatever with the idea that a municipality may take a water-works system because it has become a paying investment after years of work in building it up, and pay for it the bare cost of the physical plant. Surely there is something of value besides that. However, I do not believe that a company should have compensation given to it on the basis of a very large bonus over and above the value of that plant; that is to say, I do not believe that it is fair to pay for it on the basis of the capitalized revenue, in which the rates are more than reasonable; that is, the company should be paid for all of its work and expense, and a fair and reasonable profit, but it should not be paid for rights that have been intrusted to it by the legislature with which to serve the public, nor should it be given any monopoly value.

Now, of course, there is a question as to what are reasonable rates. I think you will all agree with me that it cannot be said that the rates in one town are reasonable or unreasonable because in another town, or in several other towns, the rates are higher

or lower. I do not believe that has very much to do with it. Each town has its own conditions of cost, and the rates to be reasonable should be based on those conditions. I should suppose that the reasonableness of rates rests mainly on the return which the company receives for its money.

The opinion of the court on these Maine cases, as I read it and understand it, was that the question of reasonable rates should have its influence on the award for compensation. Now, if rates are reasonable, or such as will give a company a reasonable rate of return upon its investment if they are to be made reasonable, then, if the award is made upon the capitalization of net revenue, it isn't going to give a tremendous bonus. As I said before, I think it is perfectly right for a company to make a good, reasonable profit, and it is entirely out of the question to expect to get water works, or the water, on the basis of the value of the physical plant only, without taking into consideration the value of the franchise or the value of the property as a going concern.

I have always been, in these cases, on the side of the municipality, not from any special choice of my own. I have the pleasure of doing other kinds of engineering work for a great many companies, but I have not been employed by companies on these valuation cases, and I suppose I am known in this connection as a municipal man. I try, however, to look at the question upon both sides and I know that there is a chance for an honest difference of opinion.

It seems to me that when works of this kind are being valued, unless it is otherwise provided for by charter or agreement, it should be on a capitalization basis, and I should like to say just a word here upon that point. There is a great deal of opposition to valuing these plants on a capitalized basis, but I cannot see, from either side of the question, why that should be opposed if it is done fairly. We will all of us agree that the cost of a thing is not always its value; there are some other considerations that come in to make up the value. For instance, if a water works was not bringing in a revenue sufficient to meet expenses, and pay interest upon the cost, no one would want to pay for those works the full cost of their construction. Now, on the other hand, why should not there be a certain increase over the cost of the con-

struction if they are paying a profit, to compensate a company for its risk in the original undertaking and its enterprise in establishing and building up the works by capitalization?

I was going to say that on that basis of valuation — and I believe that most of the works have really been valued on that basis, with a great deal of regard, at least, to that basis — everything in the way of operating expenses should be considered in ascertaining the net revenue. The true net revenue is not the gross revenue less the operating expenses, if you do not consider the depreciation of the plant. Any business man, carrying on a business in a proper way, makes provision for the depreciation of his plant. So, in a water-works system, a certain amount should be provided each year for depreciation of the plant, as municipalities do by their sinking fund, and that amount should be deducted, in addition to the operating expenses, from the gross revenue. To deduct simply the operating expenses from the gross revenue is a false way of getting at the net revenue and gives an improperly high value.

When you take all those things into consideration, and when you take into consideration, to a certain extent, the reasonableness of the rates, capitalizing the net revenue will not provide an excessive bonus over the value of the plant itself.

PROF. E. G. SMITH. Regarding the valuation of the franchise, I have never been able to satisfy myself as to the difference between valuing the franchise — which, after all, is merely a contract — and the waterworks as "a going concern." Out West we do not believe in selling a franchise, but the works are looked at as a going concern, for the franchise can have no value if it does not give some value to those who own it.

Respecting this matter of public and private ownership, there is another interesting question brought up besides that of the valuation of water works. In the West, where change from private to public ownership is going on, it is not accomplished by the establishment of a new district, as has been here brought out, but it is done under laws which allow a city to enter into contract with a private company.

The city of Kenosha, Wis., could not raise the money to establish a water system since it was bonded to the full extent, as is

unfortunately, the case with so many of our western cities, but it was possible to raise money for operation by direct taxation, by increasing the rate. Therefore it entered into a contract with a private company to build the plant, the sums which were paid in annually establishing a sinking fund which, after a certain period, would allow the return of the plant to the city. This plan has been passed upon by the Supreme Court of Wisconsin, and several cities in our state have had their works put in under this method. Of course the works ultimately revert to the city and become its property.

I hope that this extremely important paper by Mr. Eaton will be printed, and along with it the decisions of the court which he refers to. It is really an epoch-making work which has been done here, and this paper itself, and the decisions which Mr. Eaton has mentioned, the rulings of the lower and the upper courts, should have a wide circulation.

Regarding this matter of public and private water works I want to say that the Mississippi River drains a territory having a population of upwards of six millions of people from its upper to its lower extent, a population which is bound to increase. And this river, receiving as it does the drainage from this immense population, is yet the water supply of a good portion of that population.

Between Brainerd, Minn., on the north, and New Orleans on the south, not including the influent streams, there are, as has been said, twenty-six cities taking their water supply directly from the river, and of this number eighteen of the works are owned by cities or towns upon the banks, and eight of them are operated under private franchises by private corporations. Of these eight private works there is but the one, Brainerd, Minn., which has not a filtering plant, and it supplies a population of only seven thousand at the upper reaches of the river where the water is relatively pure.

The population supplied by water from the Mississippi River is almost one and a half millions; 275 000 people out of this one and a half million are supplied by private corporations, and only about seven thousand of this number are left unprotected by filtration of the water. On the other hand, of the eighteen cities and

towns supplied under public ownership, but three of them — those at Dubuque, Iowa, and at Moline and Rock Island, Ill.— filter their water or attempt to filter it in any way. And of the three cities mentioned, Dubuque takes but very little water from the river, the supply being largely from artesian wells, and at Rock Island the filter plant is unsatisfactory, leaving Moline the only city which filters the supply of water, and there the plant has been installed only since last spring. So that of this million and a half population, about a million and a quarter are supplied with water under municipal ownership, and of that number not to exceed seventy-five thousand people have a nominal protection of filtration. The other fifteen cities and towns, representing a population of about twelve hundred thousand people supplied under municipal ownership, have little protection as to the purity of their water.

This is an astonishing showing, but it brings out the other side of this question. Everybody's business, I suppose, is nobody's business. I do not say that the water companies are great charitable institutions established for the health of the people and the benefit of the nation at large. But they are alive to the public demands for waters of good quality, and suitable for all purposes, and the attempt is made to establish and operate purification plants of as high efficiency as the present condition of the science of filtration and purification can offer. Undoubtedly pressure is brought to bear upon them in order to produce results, but the facts along the Mississippi River are as I have stated.

I have been extremely interested in this question, and I think that the discussion you have here is very far-reaching. I, for one, feel very much indebted to Mr. Eaton for the splendid way in which he has brought out to us, so clearly and so fully, the work which has been done in Maine, and for the struggle which he has officered through in such a splendid manner.

THE KENNEBEC VALLEY TYPHOID FEVER EPIDEMIC OF 1902–1903.

BY GEORGE C. WHIPPLE * AND DR. E. C. LEVY.†

[*Read February 8, 1905.*]

The recent appraisals of the water works of Waterville and Augusta, Me., necessitated a careful study of the typhoid fever epidemic which swept through the Kennebec Valley during the winter and spring of 1902–3. At the time when this epidemic occurred the plan of municipal ownership through the agency of "water districts" had been suggested and the law had been pronounced constitutional by the courts. The bad quality of the water supplied to these communities had much to do with this demand for public ownership, and the outbreaks of typhoid fever naturally hastened the actions which had been contemplated. The epidemic itself presented no novel features and its history is much the same as that of many other epidemics of typhoid fever due to public water supplies. Its magnitude, however, makes it deserve a place among the important epidemics of the country.

The detailed study made necessary by the fact that testimony regarding the sanitary quality of the water supply was to be presented at the hearings and considered by the court in appraising the value of the water works is perhaps worthy of record. It is quite possible that the time may come when water companies and cities will be held legally responsible for the loss of life occasioned by such epidemics, and should this occur it might be necessary to prove in court the cause of the epidemic and the agency of the water as a distributor of infection. Those who are familiar with legal proceedings will recognize that to do this is not as easy as to study an epidemic from a purely scientific standpoint. The subject viewed in this aspect is therefore worthy of careful consideration by the members of this Association.

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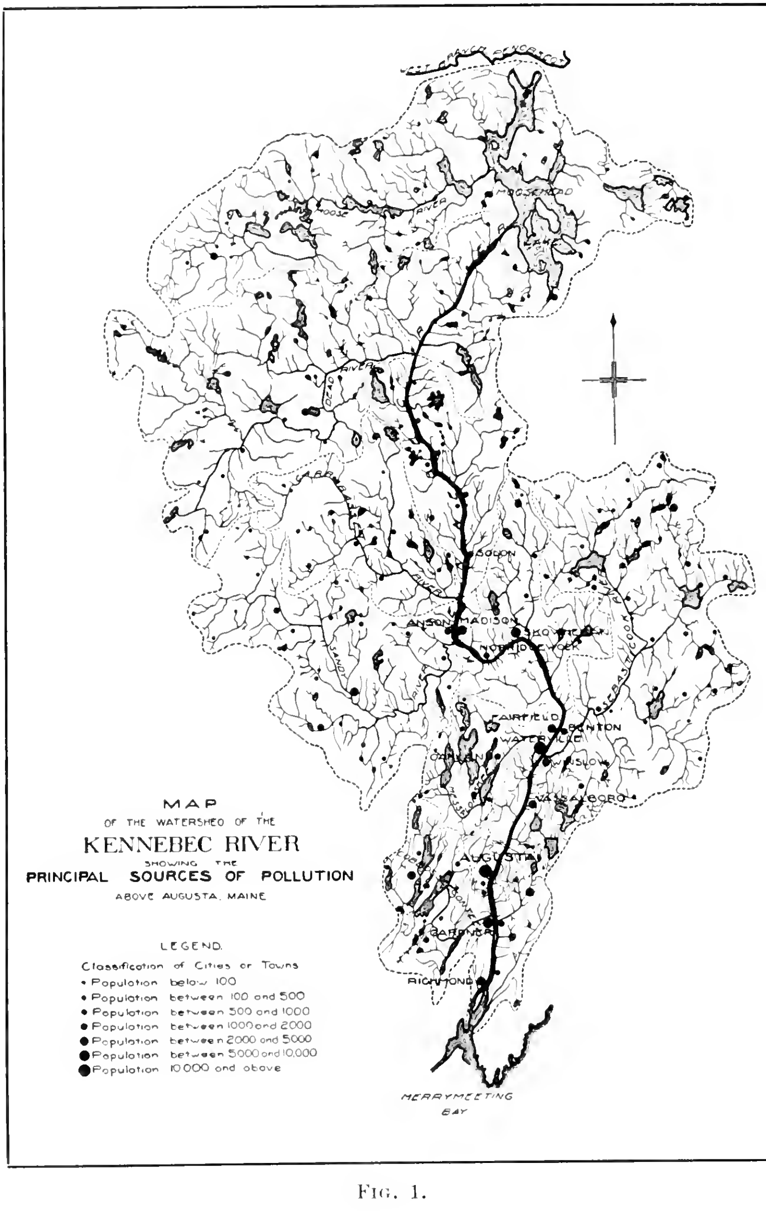
MAP
OF THE WATERSHED OF THE
KENNEBEC RIVER
SHOWING THE
PRINCIPAL SOURCES OF POLLUTION
ABOVE AUGUSTA, MAINE
LEGEND.
Classification of Cities or Towns
Population below 100
Population between 100 and 500
Population between 500 and 1000
Population between 1000 and 2000
Population between 2000 and 5000
Population between 5000 and 10,000
Population 10,000 and above
MOOSEHEAD
LAKE
MOOSE RIVER
DEAD RIVER
CARRABASSETT
RIVER
SOLON
ANSON
MADISON
SKOWHEGAN
NORRIDGEWOCK
SANDY
RIVER
SEBASTICOOK
FAIRFIELD
BENTON
WATERVILLE
OAKLAND
WINSLOW
VASSALBORO
AUGUSTA
GARDINER
RICHMOND
MERRYMEETING
BAY

Fig. 1.

In order to understand the course of the epidemic it will be necessary to sketch briefly the geography of the region so far as it relates to the water supplies of the cities involved.

GEOGRAPHICAL.

The Kennebec River drains a region, shown in Fig. 1, situated in the central part of Maine. It rises north of Moosehead Lake and flows in a southerly direction into Merrymeeting Bay, where it unites with the waters of the Androscoggin River and discharges ultimately into the Atlantic Ocean. It has a total watershed of about 6 359 square miles. The flow of the stream varies considerably at different seasons, although the storage at Moosehead Lake tends to keep it more uniform than many of the rivers of the state. There are several excellent water-powers along the stream and on its tributaries, and these water-powers have formed the nuclei of most of the cities and towns in the valley. The most important tributaries of the Kennebec River below Moosehead Lake are the Dead River, the Carrebasset River, Sandy River, the Messalonskee River, the Sebasticook River, and the Cobbosseecontee River. The most important cities and towns along the river are Solon, Anson, Madison, Norridgewock, Skowhegan, Fairfield, Waterville, Winslow, Augusta, Gardiner, Hallowell, and Richmond. It is with Waterville, Fairfield, Winslow, Benton, Augusta, and Richmond that this paper has to do. The location of these cities and towns is shown in Fig. 1.

All the cities and towns along the river naturally drain into the stream, so that in the lower courses of the river the water is considerably polluted. This is shown by Tables No. 1 and No. 2, which give the population per square mile and the amount of sewage and manufacturing wastes entering the stream at various places above Augusta, and also in Fig. 2, which shows the drainage areas and populations above various points.

The city of Waterville and the neighboring towns of Fairfield, Winslow, and Benton, were, at the beginning of this investigation, supplied by the Maine Water Company with water from the Messalonskee stream. This stream has a watershed of 205 square miles above the pumping station and drains a chain of seven large

lakes which have a combined water surface of 27.5 square miles. Upon this watershed there dwells a population of something over five thousand persons, or about twenty-seven per square mile. The upper portions of the watershed are comparatively unpolluted, but at the outlet of Messalonskee Lake is the town of Oak-

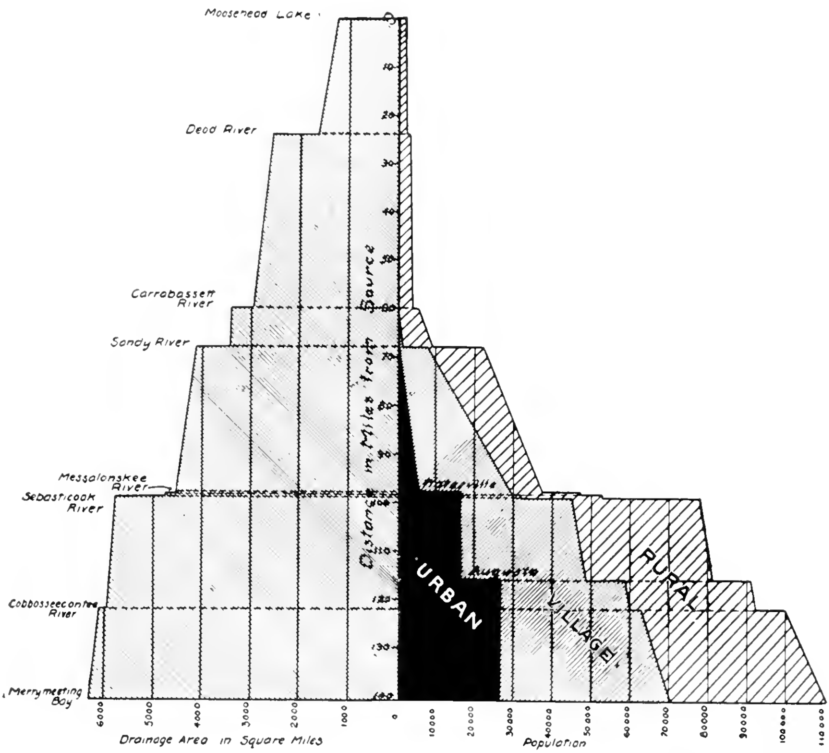

FIG. 2.— DIAGRAM SHOWING THE DRAINAGE AREA AND POPULATION ABOVE VARIOUS POINTS ON THE KENNEBEC RIVER.

land which has a population of approximately two thousand. At this place, which is only seven miles above the pumping station of the Maine Water Company at Waterville, sewage is discharged from several private sewers. Along the stream are a number of mills, the most important of which are the Oakland and Cascade

Woolen Mills, the mills of the Dunn Edge Tool Company and the Emerson and Stevens Company. They contribute not only a considerable amount of fecal matter, but wool washings, dye stuffs, and other kinds of manufacturing wastes. The Messalonskee River between Oakland and Waterville flows rapidly during the first half of its course and then somewhat more slowly as it feels the effect of the backwater of the water-works dam. The time required for the water to flow from Oakland to Waterville is often only a few hours. The Maine Water Company had also the right to use the water of the Kennebec River. This water has been seldom used, although just prior to the epidemic it was pumped into the city for a short time because of a fire which occurred at Colby University. During the dry spell of last autumn (1904) it was again used, as the flow of the Messalonskee became insufficient to operate the pumps.

As might be naturally expected from the surroundings, the water at the pumping station of the Maine Water Company showed decided indications of pollution. Under ordinary conditions the water was light colored and fairly clear, but after rains it became turbid and heavily laden with bacteria. At all times the intestinal germ, *B. coli*, was present in large numbers.

Prior to 1901 the typhoid fever death rate in Waterville had not been especially high. During 1901 and 1902, however, the rate increased to more than 80 per 100 000, but it was not until the autumn of 1902 that the typhoid situation became serious.

The city of Waterville is fairly well provided with sewers, and at Waterville, Winslow, and Fairfield there are a number of mills which have privies directly over the stream.

About eighteen miles below Waterville is the city of Augusta, the capital of the state. Augusta takes its water supply directly from the Kennebec River at a point just above the city near the Kennebec Dam. Until recently the works were owned by the Augusta Water Company. The river water was pumped to a reservoir, but was first passed through an old Warren filter, one of the first of its kind in America. This was a filter only in name, and should have been more properly called a strainer. Analyses indicated that its bacterial efficiency was practically *nil*. As would be naturally expected, the river water at Augusta was

found to be polluted. This was shown by the analyses which were made daily for several months, but it was even more strongly demonstrated by the typhoid fever statistics of the city.

The water of the Kennebec River just below Waterville showed at all times evidences of gross pollution. During its flow of seventeen miles to Augusta its bacterial quality appeared to improve somewhat. In the summer this improvement was much more noticeable than during the winter, when the river was covered with ice. Float experiments which were made indicated that the time required for water to flow from one place to the other was about three days at times when the discharge of the stream was small. At times of flood this period is probably not much, if any, more than twenty-four hours.

The Augusta Water Company also controlled and used a spring water supply known as the Devine water. In some houses this was used exclusively, in others both this and the river water was used. The quality of this water was poor, but better than that of the river.

The sewers of Augusta discharge into the river and there are several mills along the shore which pollute the water.

The town of Richmond, fifteen miles below Augusta, also takes its water supply from the Kennebec River. The conditions there are such that the main current of the stream flows to the east of Swan Island, while the intake of the water works is located in the west channel. The river at Richmond is considerably affected by the tides; in fact, the town water is at times brackish. Thus, while the town uses the water which receives the sewage of Augusta, Waterville, and other cities, the tidal conditions tend somewhat to lessen the effect of this up-stream pollution, although they increase the danger from local sources.

GENERAL ACCOUNT OF THE TYPHOID FEVER EPIDEMIC.

The typhoid fever epidemic of 1902–3 began about the middle of November, 1902. It was first noticed at Waterville, where for about a month new cases were reported at the rate of one a day. On Christmas day there were five new cases and during the next week the daily number of cases was the same. Thirteen were reported on New Year's day. After the middle of January

the number of new cases fell off, but they continued to be reported at intervals until March. In Fairfield, Winslow, and Benton, typhoid fever occurred at the same time. The largest number of cases was reported during the first two weeks of January. These four communities had the same water supply, namely, that of the Messalonskee River, and from the first it was evident that this was the cause of the epidemic.

As the sewage of these typhoid fever stricken communities emptied into the Kennebec River and as the water of this river furnished the supply of Augusta, it was almost inevitable that the epidemic should extend to that city also, and this is what actually occurred. During the latter part of November and the whole of December new cases of typhoid fever occurred daily in Augusta. It seems probable that these earlier cases were due to the same source of infection that caused the epidemic at Waterville, inasmuch as the Messalonskee River which supplied that city discharges into the Kennebec above Augusta. It was not until about two weeks after the climax of the Waterville epidemic that the serious period of the Augusta epidemic began. During the latter part of December and throughout the months of January and February the sewage at Waterville must have been infected with typhoid fever bacilli; and, making due allowances for the periods of sickness, transmission, and incubation, this time corresponded with the duration of the epidemic at Augusta. After the Waterville epidemic had ceased and sufficient time had elapsed for the patients to recover, the epidemic at Augusta came to an end.

At Richmond, which is only a small village, typhoid fever did not occur until the middle of January, but occasional cases appeared during the next two or three months and were plainly connected with the epidemic of the cities above.

The city of Gardiner is situated between Augusta and Richmond. It does not take its water supply from the Kennebec River, but from the Cobbosseecontee River. This city had no epidemic, although a number of cases of typhoid fever occurred there. Most of these were contracted at Augusta. The same was true also of the town of Hallowell.

Fig. 3 shows chronologically the progress of this epidemic, together with certain factors which affected it. It indicates

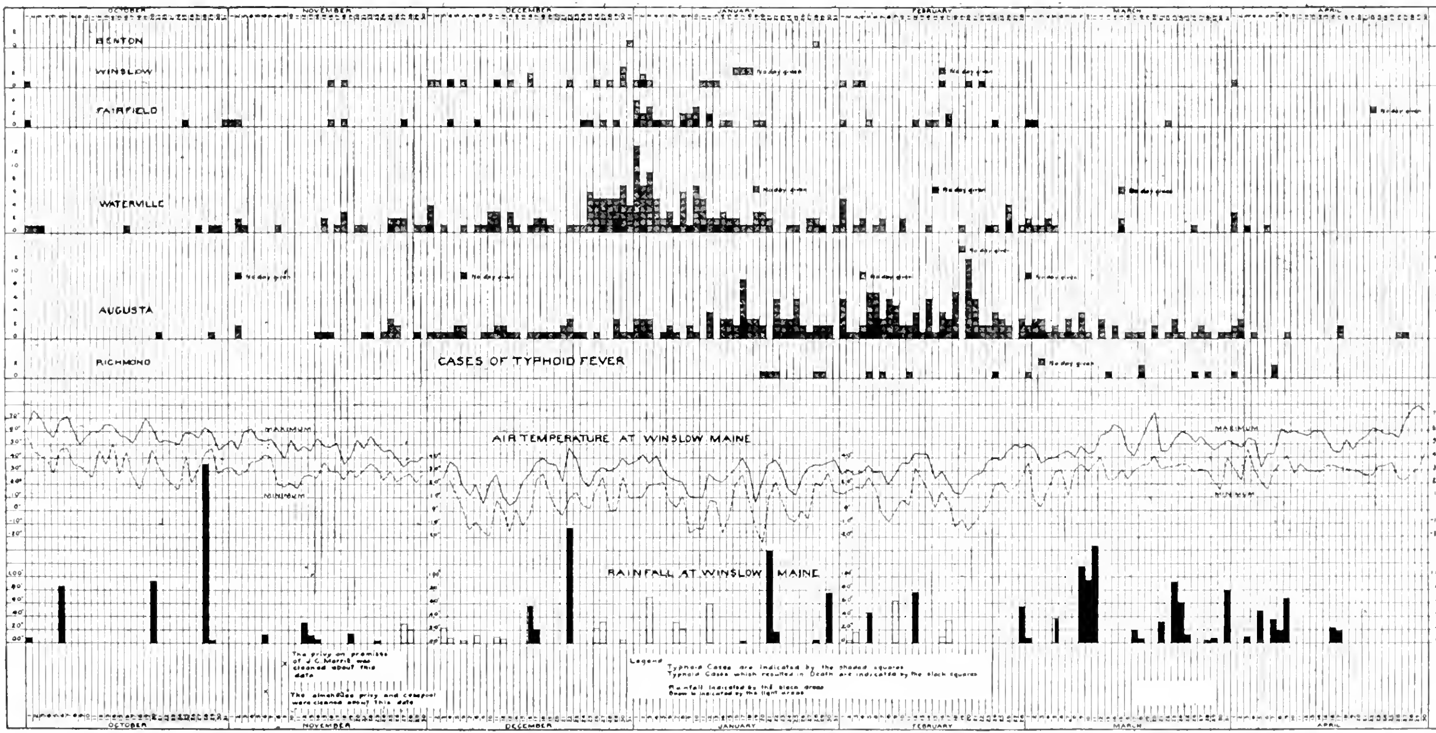

FIG. 3.—DIAGRAM SHOWING THE CHRONOLOGICAL DISTRIBUTION OF TYPHOID FEVER CASES IN WATERVILLE, FAIRFIELD, WINSLOW, BENTON, AUGUSTA, AND RICHMOND, MAINE, FROM OCTOBER, 1902, TO APRIL, 1903.

that the epidemics in the different communities formed a connecting series and may be really considered as one epidemic, inasmuch as they started from a common cause. In all there were about 612 cases and 53 deaths.

INVESTIGATION OF THE EPIDEMIC.

The investigation of the Kennebec Valley typhoid fever epidemic was made with unusual completeness. It was not only desirable to ascertain the cause of the infection and the agency of transmission in order to protect the health of the citizens, but it was necessary to prove beyond a doubt whether or not the water supply was a potent factor in spreading the disease, as the quality of the water was intimately involved in the valuation of the water works, both at Waterville and Augusta. In January, 1903, one of the writers* was retained by the Kennebec Water District to investigate the quality of the water supply and to study in detail the relation between it and the typhoid fever epidemic above described. In August he was also retained to make a similar investigation for the Augusta Water District. The whole investigation included a thorough sanitary survey of the watersheds of the Kennebec and Messalonskee rivers, a long series of analyses of the water supplies and a study of the epidemics above mentioned, besides many local studies of a subsidiary character. Incidentally, investigations were made looking towards the future supplies of both cities. It was necessary not only to study all of these subjects from a scientific standpoint, but to prepare the data in the form of legal evidence to be presented in court. This paper relates only to those portions of the work which had to do with the typhoid fever epidemic.

TYPHOID FEVER IN WATERVILLE.

In studying the Waterville epidemic the first step taken was to secure with as much accuracy as possible certain information in regard to each case of typhoid fever. Printed forms, a sample

* This work was in charge of Mr. Whipple. At Waterville he was assisted by Dr. E. C. Levy; at Augusta, by Mr. Langdon Pearse, Sanitary Engineer, and by Dr. H. L. Russell, bacteriologist of the State Laboratory of Hygiene. Similar investigations on the part of the private water companies were made by Mr. James M. Caird, assisted by Mr. Percy N. Coupland, bacteriologist.

of which is given below, were first distributed among the physicians, who were requested to fill them out and furnish any other important facts known to them in regard to each case of typhoid fever which they had attended.

Typhoid Fever Record.

Case No. ....
Name ....Residence ....
Sex ....Age ....years .... months ....
Nationality ....Occupation ....
Attended by Dr. ....of ....
Date of first symptoms..............First saw physician ....
Where living for month preceding illness, including absences from home....
....
Source of water used regularly for drinking:
1. At home ....
2. At place of business ....
Other water occasionally drunk ....
Milk supplied by ....Address ....
Ice ....
Other cases in house ....
Other cases among business associates ....
Other cases where visiting ....
Were stools disinfected during illness?....................................
Termination of illness { Recovery, date of leaving bed ....
{ Death, date ....
Number of people in house ....
Remarks: ....
....
....
Date of above report ....Information given by ....

While waiting for the return of these blanks from the physicians, the records of the local Board of Health were consulted. As fast as the returns were received from the physicians, each house where a case of typhoid fever had occurred was visited by an inspector, who examined the surroundings, checked up the data recorded upon the blanks, and obtained as many additional data as possible. He also secured the name of the person furnishing the information, in case it became necessary to call witnesses in court, and finally signed the completed record. Duplicate copies of the blanks were made with carbon paper and one of each placed in a

safe to guard against possible loss. The results were then tabulated for study and in some instances expressed graphically.

Data were also collected regarding the previous history of typhoid fever in the city. Similar data were obtained from Fairfield, Winslow, and Benton. These tables, No. 3 to No. 9, were used in the Waterville hearing before the Board of Appraisers.

The first typhoid canvass was followed by a complete house-to-house canvass throughout the four places above mentioned, primarily in order to secure data in regard to the water used, but also to obtain information as to the distribution of typhoid fever among users of different classes of waters. This not only accomplished its immediate object, but brought to light a number of additional cases of typhoid fever which the physicians had failed to report, some of which might be classed as "walking cases." No case however, was included in the final compilation until it had the indorsement of the attending physician.

It is not necessary to relate in detail all the steps that were taken. Studying the etiology of the epidemic by the method of elimination, all possible causes other than the public water supply were readily excluded. It could not have been caused by flies, because at the season of the year when the epidemic started, there were no flies. Ice was excluded, because during the winter practically no ice was being used. Oysters were eliminated, because very few of them were consumed in the city, and because a very large part of the epidemic occurred among the French-Canadian laboring people who seldom purchased them. Furthermore, the extended territory covered by the epidemic was in itself sufficient to exclude the above agencies. Milk was excluded as a general cause, because the data collected indicated, as shown in Fig. 4, that the cases of typhoid fever were not concentrated among the customers of one or a few milkmen, but were well distributed among the different dealers. The distribution was found to be roughly proportional to the size of the business and the number of cows kept. It was a singular fact that there was no case of typhoid fever among the customers of J. W. Morrill, in whose family one of the initial cases of the epidemic occurred.

Vended spring waters were excluded, because the users of this class of water suffered far less than others, because the spring

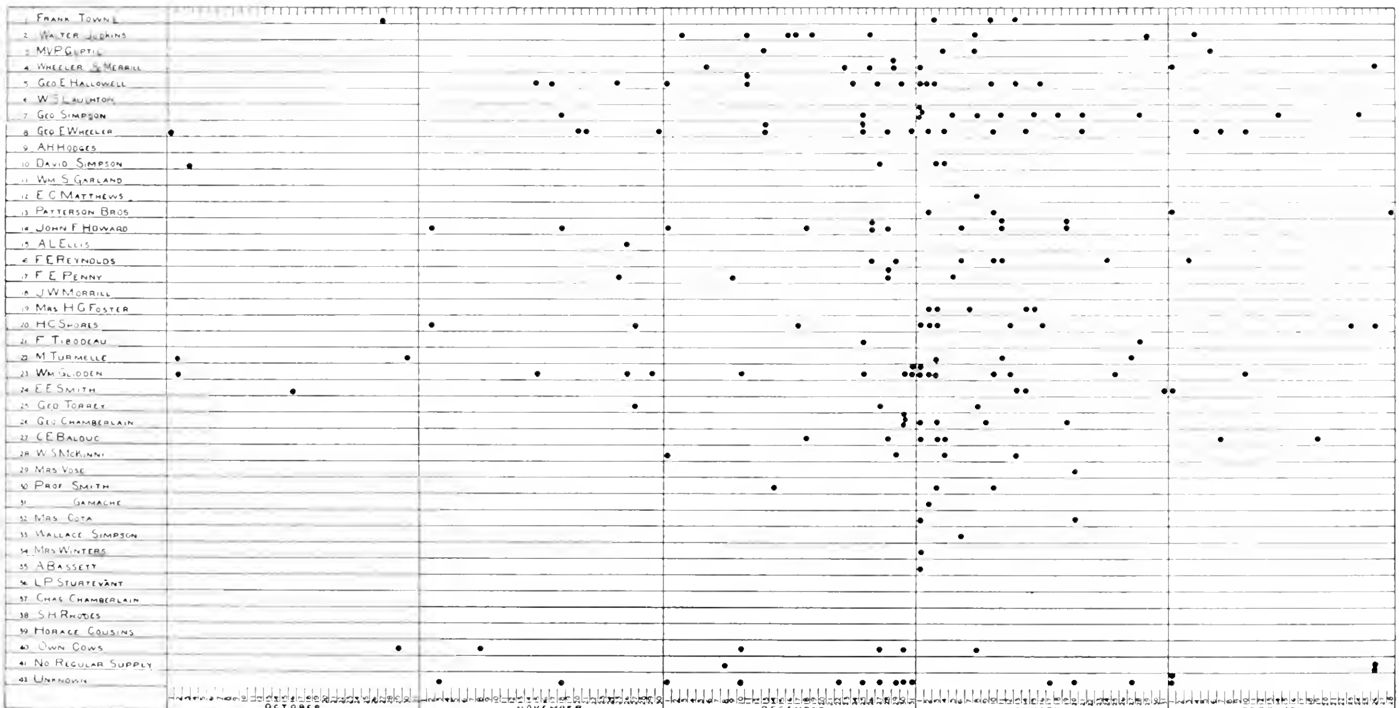

Fig. 4. — Diagram Showing the Distribution of Typhoid Fever Cases among Customers of the Milk Dealers in Waterville, Maine, between October 1, 1902, and March 1, 1903.

waters gave excellent analyses and because the water from no single spring, or group of springs, was used over the entire territory affected. The local wells were studied by us to some extent and quite extensively by Mr. Caird. Many were found to be polluted, as would be naturally expected from the local conditions, but there was no evidence by which infection could be traced to any one of them.

Practically the only cause left for serious consideration was the public water supply of the city, the cause to which everything had directly pointed from the start. The general distribution of the cases over an extensive territory (the various parts of which had in common no possible causative factor other than the water supply), as shown in Fig. 5, the chronological sequence of the cases, the fact that in practically every instance the patients gave a history of having regularly or occasionally drunk the water in question, the data obtained as to the relative prevalence of typhoid fever among users and non-users of this water throughout the district, and, lastly, the discovery of the actual means by which the water had in all likelihood become infected, — all these things indicated with as much positiveness as is possible with circumstantial evidence that it was the public water supply which was the general distributing agent of the infection.

For some time prior to the epidemic, the character of the water supply of the city had been such as to lead to a quite general use of spring water, which was peddled by several dealers and purchased by most of those who could afford it. Well and cistern waters were used to a considerable extent. The water of the Kennebec River was used at a number of the mills and in some residences, especially in Winslow. The figures obtained in the general canvass and given in Tables No. 8 and No. 9 were of considable interest in this connection. They showed that the morbidity rate for the epidemic period among those who used Messalonskee water exclusively was 42.00 per 1 000; while among these who used Messalonskee and some other water it was 14.55. If from the latter class there were excluded those who used water from the Kennebec River, which at Waterville is more or less polluted, the morbidity rate was found to be only 8.74. It is not to be expected that even in this group there would not be some who had

occasionally used water from the Messalonskee supply, for, as a matter of fact, there were only five of the Waterville typhoid patients who did not remember to have used this water at any time before being taken ill.

The figures given show emphatically that the morbidity rate was highest among those who used the Messalonskee water exclusively and lowest among those who did not use it. It must be remembered, of course, that in any epidemic there are always some cases contracted by direct infection from other cases.

In Fairfield, many of the houses were supplied by water piped from a spring by a private company. Not a single case developed among the takers of this water.

ORIGIN OF THE EPIDEMIC.

As soon as it had become evident, not only from the exclusion of other possible causes but from certain well-marked positive features of the situation, that the epidemic was due to drinking water, a search for the actual origin of the infection of the public water supply was begun. Our attention naturally was first directed to Oakland, as this was the only settlement of considerable size on the Messalonskee River above Waterville. Inquiry among the Oakland physicians elicited the information that there had been but one case of typhoid fever there during the preceding summer and fall, up to the beginning of the Waterville epidemic. This case had been imported from Winslow. An inspection of the premises where the patient resided convinced us that this could not possibly have been the starting point of the Waterville epidemic.

Very soon after the returns from the typhoid canvass began to come in, two possible sources of infection of the city water supply suggested themselves, and further investigation of these rendered it reasonably certain that each of them had offered abundant opportunity for the infection of the Messalonskee River.

The first of these foci was at the city almshouse, located in the suburbs of Waterville near the Messalonskee stream, as shown in Fig. 5. A typhoid fever patient, Joe King, was admitted there on September 22, 1902. His attack was a mild one and confined him to bed for only a week. After leaving his bed, however, he remained five days longer at the almshouse, and dur-

ing this latter period no attempt was made to disinfect either excreta or urine, which were deposited sometimes in a privy in the yard and sometimes in a watercloset which drained into a cesspool on the premises. On November 6, 1902, the privy and cesspool were cleaned and their contents spread upon the almshouse garden, the ground being frozen at the time. This was only a few hundred feet from the Messalonskee River, into which it drained. The slope of the intervening land was quite steep and there was also a distinct gully which showed every sign of carrying a considerable and rapid flow of water across the garden and into the river after heavy rainfalls.

The second focus of infection was found about a mile outside of Waterville, on the other side of the stream. During 1902, there had been five cases of typhoid fever in the families of J. W. Morrill and J. C. Morrill, who lived in farmhouses situated just across the road from each other. In all of these cases except one, a prompt diagnosis had been made and the fecal dejecta of the patients had been disinfected and buried daily. In the second case of the series, however, the patient, Mrs. Studley, had been ill several weeks before the diagnosis of typhoid fever was made. During this time, *i. e.*, from September 1 to September 25, no sufficient disinfection of stools was practiced, but they were emptied directly into a privy vault. Later on, at some time early in November, the contents of the privy were deposited in a field at a point where the land sloped abruptly towards a rivulet, about 200 feet away. After flowing about three quarters of a mile, over a very rapid course, this brook emptied into the Messalonskee River almost directly opposite the almshouse above mentioned, about one mile up-stream from the intake of the water works. (See map, Fig. 5.)

Thus, early in November, 1902, there were typhoid dejecta deposited upon the surface of the frozen ground at two points above and relatively near the pumping station of the Maine Water Company. In each case there was a sharp slope from the point where the dejecta were deposited, — to the Messalonskee River in the one case, and in the other to a small rill which emptied into the river. If these were the sources of infection, one would expect that, from this time on, the occurrence of typhoid fever among

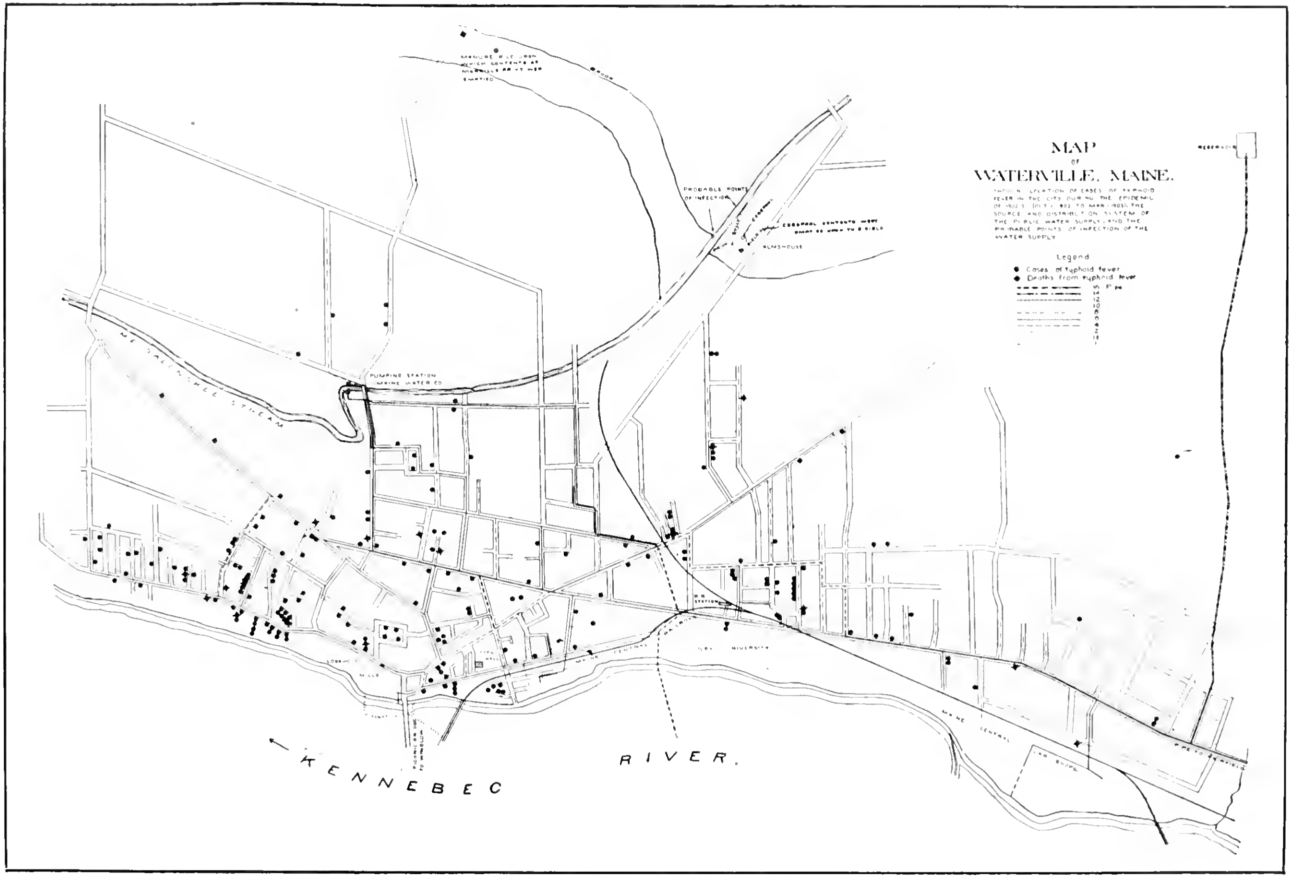
MAP
OF
WATERVILLE, MAINE.
Legend
Cases of typhoid fever
Deaths from typhoid fever
PROBABLE POINTS OF INFECTION
ALMSHOUSE
PUMPING STATION MAINE WATER CO.
KENNEBEC
RIVER.

FIG. 5.

users of the Messalonskee water would bear an intimate relation to the rainfall. This relation was found to exist.

Fig. 3 shows the date of occurrence of the typhoid fever cases, as determined by the date of physician's first visit, — which was found to be in most cases the day when the patient took to bed, — in Waterville, Fairfield, Winslow, and Benton, during the months of November, 1902, to February, 1903. The daily rainfall as recorded at Winslow is also shown. From this table it seems that during the early part of November there was only what may be considered a normal number of typhoid cases for this season. The first rainfall of considerable extent after infectious material was deposited in the fields was on November 12, when there was .30 inch. This was followed by a small group of cases towards the end of the month. The precipitation between November 23 and December 16 was snow, and this, gradually melting, probably washed small amounts of infectious matter into the river, which gave rise to the cases which developed up to about December 24. On the 16th day of December, there was a precipitation of .56 inch, rain and snow, and nine days later, December 25, the real epidemic may be said to have begun, with the development of six cases of typhoid in Waterville and one in Fairfield. From December 25 to the end of the month there were 37 cases in Waterville, 5 in Winslow, 3 in Fairfield, and 1 in Benton, a total of 46 cases in one week.

The heaviest rainfall after the infectious material was deposited on the fields at Morrill's and the almshouse occurred on December 22, 1902, when there was a precipitation of 1.73 inches. Ten days after this, or almost exactly the same interval as after the rainfall of December 16, there developed the greatest number of cases of any day during the epidemic, namely, 13 cases in Waterville, 4 in Fairfield, and 1 in Winslow, a total of 18 cases.

Throughout the two months from the last third of November until the corresponding time in January, the relation between the rainfall and the typhoid cases was manifest as shown in Fig. 3. By the middle of January the typhoid bacilli in the two mentioned fields had either lost their vitality, or, what is more likely, had been pretty thoroughly washed away; for a rainfall of 1.40 inches on January 21 was not followed by any serious consequences.

The constant relation between rainfall and the development of typhoid fever cases was in itself a strong argument in favor of the agency of the public water supply in causing the epidemic.

In attempting to prove the case in court there were produced as witnesses the physician who attended the initial cases, the persons who spread the cesspool and privy contents on the fields, the inspector who had charge of the typhoid canvass, and the writers who collected the data and made the various investigations here referred to.

Although it is impossible in a paper of this length to give details of every piece of evidence presented, it may be well to take notice of a plausible objection to the above theory which might have been brought forward. During the early part of the epidemic Fairfield did not have as many cases in proportion to its population as did Waterville and Winslow, although supplied to a great extent by the same water. This was readily explained by a consideration of certain features of the distributing system. The reservoir of the system is located between Waterville and Fairfield and is supplied by a single pipe line, which branches off from the main connecting the two cities. From this arrangement it follows that when the consumption in Waterville and Winslow is less than is being pumped, both places receive water directly from the pumps, the excess going to the reservoir. When, on the other hand, the consumption is greater than the amount pumped, Fairfield and Benton receive water which has been stored in the reservoir. This fact was proved experimentally during our investigations by making several series of analyses at various points in the system. The older water in the reservoir, which had received some sedimentation, would be theoretically less infected with typhoid bacilli than the water pumped directly from the river; and theory, in these cases, certainly agreed with the facts. The facts also indicated that the use of the Kennebec River water at the time of the Colby University fire could not have been the cause of the epidemic or have materially contributed to it.

From the standpoint of the appraisal, the point to be established was not that the two cases mentioned were or were not the cause of the epidemic, but that *the public water supply* was or was not

responsible for it. All the studies were incident to this main proposition.

TYPHOID FEVER IN AUGUSTA.

The methods used in studying the epidemic in Augusta were similar to those employed at Waterville. The house-to-house canvass was perhaps more thorough, but on the other hand it was made several months after the epidemic was over, when the facts were not so fresh in the minds of the people. The studies of the previous history of typhoid fever in Augusta were much more important than in the Waterville case, and the problem was much more complicated because the city had two sources of public water supply and the number of spring waters sold was greater.

PREVIOUS HISTORY OF TYPHOID FEVER IN AUGUSTA.

The Kennebec River water was introduced as a source of public water supply in the year 1887. For sixteen years before that time the average typhoid fever death rate in August had been 36.5 per 100 000; for sixteen years from 1888 to 1903 the average rate was 85.4. In 1898 there were a number of imported cases due to the Spanish War, and in 1903 occurred the great epidemic, which raised the death rate to 259 per 100 000. Excluding these two years, the average death rate during the period covering the use of the Kennebec River water was 66.5, or nearly double what it formerly had been.

At various times prior to 1903, typhoid fever had been prevalent in the city. Thus the board of health records for 1890 show that seventy-five cases of typhoid fever, besides a large amount of winter cholera, occurred that year. During the first thirteen weeks of 1891 sixty-nine cases were reported. There were no typhoid fever records kept at Waterville at that time, so it cannot be told whether or not the disease was due to infected sewage from that city. Typhoid fever was also prevalent during the winter and spring of 1892 and 1893. A report made by Capt. M. W. Wood, assistant surgeon, U. S. A., on June 2, 1893, states that there were about one hundred cases during the early part of that year.

Prior to the introduction of the Kennebec River water, typhoid fever in Augusta had been most common in the autumn, this

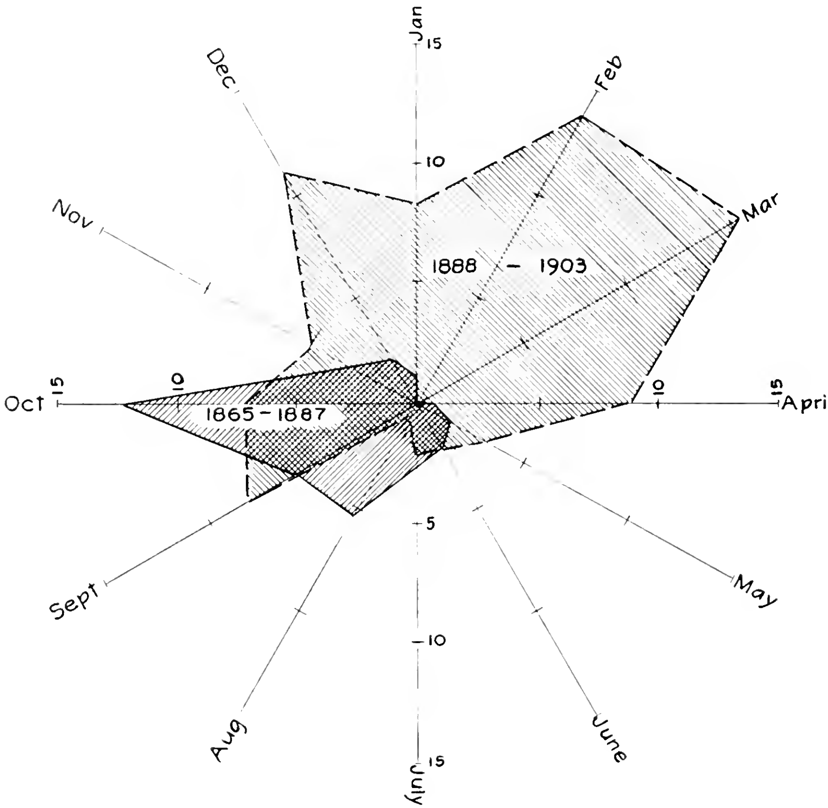

DIAGRAM SHOWING THE
SEASONAL DISTRIBUTION OF
TYPHOID FEVER
IN AUGUSTA MAINE
BEFORE AND AFTER THE INTRODUCTION
OF KENNEBEC RIVER WATER

The figures on the radial lines stand for monthly death rates.

Fig. 6.

being the normal season for the maximum of the disease, but after the installation of the supply from the Kennebec River the disease became most common during the winter months. This is an abnormal seasonal distribution, and is most easily explained by assuming the maximum of the disease at Augusta to follow and to be caused by the normal autumnal maximum of typhoid fever in Waterville and the other cities which discharge their sewage into the river above Augusta. This change in the seasonal distribution is shown in Fig. 6.

Both the abundance of typhoid fever and its seasonal distribution since 1888 pointed strongly to the pollution and infection of the river water and would have been sufficient to condemn it as a source of supply even if the epidemic of 1902–3 had not occurred.

The data compiled for the Augusta epidemic are given in Tables 10 to 17, and are shown graphically in Figs. 3 and 7. As in the case of Waterville, all possible agencies of infection other than water were one by one excluded from consideration. The canvass showed that the morbidity rate for those cases on premises supplied with river water only was 53.7 per 1 000; on those supplied only with Devine water, 12.3; and on those supplied by wells, springs, or cisterns, 23.6. On those premises supplied with river water with or without supplementary sources the morbidity rate was 29.2, while on those which had no river water the rate was 20.6.

Classifying the cases according to the statements of the patients as to their use of water it was found that of 336 cases 76 per cent. admitted that they had used the river water prior to being taken sick, while 24 per cent. of them did not remember to have used the water. Of the latter class, however, 65 per cent. lived on premises supplied with water from the river. Thus only about eight per cent. of the patients interviewed did not remember of having used the water and were not supplied with water from the river, at their homes. The conclusion that the river water caused the epidemic was inevitable.

Some of the data collected during the investigation are given in the tables referred to and need no special comment.


MAP OF
AUGUSTA MAINE
SHOWING LOCATION OF
TYPHOID CASES DURING
THE EPIDEMIC OF 1902-1903
LEGEND
Kennebec
River

FIG. 7.

TYPHOID FEVER AT TOGUS.

The National Home for Disabled Volunteer Soldiers, Eastern District, is located at Togus, about six miles from Augusta. At the time of the investigation there were 2 260 members and 40 civilian employees. The Home was established in 1867 and its location was chosen because of the supposed medicinal virtues of a certain spring known as Togus Spring, which is still used by some of the members. Prior to 1887 the water supply of Togus was taken from Greely Pond, but as it was insufficient in quantity and not entirely satisfactory in its physical qualities, water from the Kennebec River was introduced in June, 1887. Between 1877 and 1887 not a case of typhoid fever occurred among the members, but during the fourteen years from July 1, 1887, to June 30, 1891, 25 cases occurred, which resulted in five deaths. When the old age of the members is taken into consideration this number appears large. The prevalence of typhoid fever at this time was attributed by Dr. Ellwell, surgeon, U. S. A., to the use of the Kennebec River water, and at his instigation a new supply was provided in 1892 from a spring known as the Hallowell spring. This is piped into most of the buildings and is almost exclusively used for domestic purposes. Its quality is good. Although the use of the Kennebec River water was forbidden, it was impossible to entirely prevent its use, and this probably accounts for the scattering cases of typhoid fever which have occurred there during the past twelve years. After the introduction of the Hallowell Spring water there was an almost immediate disappearance of the disease. No case of typhoid fever occurred at the Home during the epidemic of 1902–3.

TYPHOID FEVER AT THE MAINE INSANE HOSPITAL.

The state insane hospital is located in Augusta but has a separate water supply for drinking and domestic purposes. The Kennebec River water is more or less used. Between 1865 and 1887, with an average number of 404 patients, no deaths from typhoid fever occurred. This was before the introduction of the river water. Between 1887 and 1902 the average number of patients was 670 and the number of deaths from typhoid fever 6, which is equivalent to an annual death rate of 56 per 100 000.

TYPHOID FEVER AT RICHMOND.

The typhoid fever records of Richmond do not extend back of 1892. The city clerk's records for the years 1892 to 1903, however, indicate a death rate of 42 per 100 000 during these twelve years.

The typhoid fever canvass of Richmond was less complete than that of Augusta, but of the 19 cases which occurred between January and April, 1903, all were said to have used the river water, and there is little reason to believe that these cases were due to any other cause.

GENERAL TYPHOID FEVER SITUATION IN THE STATE OF MAINE.

For a number of years the death rate from typhoid fever in Maine has been greater than for most of the other New England states. Some of the cities have maintained death rates which reflect in the most uncomplimentary manner the quality of their public water supplies.

It is sad to have to recount that the epidemic of the Kennebec River was duplicated one year later on the Penobscot River. This epidemic has not been studied with as much care as the one described above, and all the circumstances are not fully known to the writers.* The general facts, however, were as follows:

The epidemic appears to have originated in Millinocket, a paper-mill town located about ninety miles north of Bangor. This village is said to be supplied with water from the river at two places, one above the town and one so near the town that it receives considerable pollution. Ordinarily the upper source is used, but early in the year 1904 a fire occurred which compelled them to use water from the lower intake. This was followed by an epidemic of dysentery, but no typhoid fever. A short time afterwards a second fire occurred, which again necessitated the use of the polluted water. This time an epidemic of typhoid fever resulted, which was so serious that it became necessary to call in physicians from outside the town in order to take care of the large number of cases which occurred. The infection passed

* Since the preparation of this paper the Penobscot River epidemic has been carefully investigated by Mr. Whipple in the interest of the Citizens' League of Bangor. The results only serve to emphasize the statements here made.

down the Penobscot River and affected Oldtown, Brewer, and Bangor, all of which places take their water from the river. At least seventy-five cases are known to have occurred in Oldtown, but complete data on this subject are not at hand. The epidemic at Bangor was studied with considerable care by a committee of citizens headed by Dr. Bertram L. Bryant. This committee published a series of interesting reports which appeared from time to time in the Bangor *Daily Commercial*, and which were afterwards published in pamphlet form by the Citizens' League. From this report it is learned that between March 1 and May 24, 1904, 540 cases of typhoid fever and thirty-three deaths occurred in Bangor. The committee estimated that one person in every forty of the people of Bangor had typhoid fever during these three months.

A sanitary inspection of the watershed was made by P. H. Coombs, civil engineer, who made a report which contained data as to the amount of sewage entering the river between Oldtown and Bangor. Analyses showing the quality of the river water were made by Prof. Franklin C. Robinson. The water supply of Bangor was filtered through a mechanical filter of an old type, but it was evidently entirely inadequate for the purpose of purifying the water. Strangely enough, almost no allusion is made in this report to the Millinocket epidemic as being the cause of the others, but this was undoubtedly the case.

The lesson of these two river valley epidemics ought to be taken seriously to heart by the sanitary authorities of the state of Maine. For a community to use as a public supply an unfiltered water taken from a river which receives the sewage of cities higher up is only to invite disaster. It is unfortunate that such conditions are not remedied before rather than after the occurrence of an epidemic. The cities of Waterville and Augusta and the cities of the Penobscot valley could have satisfactorily filtered their water supplies for a small part of what the epidemics cost them, and many lives might have been saved. The water companies in charge either did not appreciate the danger or they were not willing to incur the expense of rendering the water safe. One result of this situation is that the public water supplies are being taken away from the companies and purchased for the people by the so-called water districts.

Yielding to the popular prejudice against the use of the water which caused the epidemic, several cities have chosen to seek new supplies elsewhere. The new water supply for Waterville is to be taken from China Lake, and that for Augusta from Carleton Pond, both supplies being eminently satisfactory from a sanitary standpoint, and of such a character that they will not need filtration for many years to come. Brunswick is obtaining a new supply from driven wells. In many of the cities of the state, however, it would probably be cheaper to maintain their present sources of supply and protect the quality of the water by filtering it.

The state board of health of Maine now has a hygienic laboratory at Augusta, and in no way could this laboratory be made more serviceable than by establishing a systematic examination of the water supplies of the state in order to point out which of them are good, which are insecure in their sanitary quality, and which, if any, are dangerous. This should be supplemented by a sanitary inspection of the watersheds from which the various sources of supply are derived. To do this work would require a comparatively small increase in the appropriation, and its cost would be repaid a thousandfold, not only in dollars and cents, but in human lives.

TABLE No. 1. — Drainage Area and Population on the Watershed of the Kennebec River at Various Points.

Distance in Miles.	Drainage Area.	Drainage Area in Square Miles.		Population. Rural.		Population. Village.		Population. Urban.		Population. Total.		Population per Square Mile. Rural.		Population per Square Mile. Village.		Population per Square Mile. Urban.		Population per Square Mile. Total.	
0	Moosehead Lake, at outlet,	1 260		1 730		0		0		1 730		1.4		0		0		1.4	
	Between Moosehead Lake and Dead River,	378		210		0		0		210		0.5		0		0		0.5	
	Total above Dead River,		1 638		1 910		0		0		1 910		1.2		0		0		1.2
24	Dead River,	947		1 130		0		0		1 130		1.2		0		0		1.2	
	Between Dead River and Carrabasset River,	377		250		0		0		250		0.7		0		0		0.7	
	Total above Carrabasset River,		2 962		3 320		0		0		3 320		1.1		0		0		1.1
60	Carrabasset River,	439		3 370		0		0		3 370		8.0		0		0		8.0	
	Between Carrabasset River and Sandy River,	33		610		1 380		0		1 990		18.0		42.0		0		60.0	
	Total above Sandy River,		3 434		7 300		1 380		0		8 680		2.1		0.4		0		2.5
68	Sandy River,	732		6 820		6 330		0		13 150		9.0		9.0		0		18.0	
	Between Sandy River and Waterville,	400		3 520		6 760		5 180		15 460		9.0		17.0		13.0		39.0	
98	Total above Waterville,		4 566		17 640		14 170		5 180		37 290		3.9		3.2		1.1		8.2
99	Messalonskee Stream,	205		2 450		2 940		0		5 390		12.0		14.0		0		26.0	
	Sebasticook River,	1 041		11 580		13 760		0		25 340		11.0		12.0		0		23.0	
	Between Waterville and Augusta,*	115		950		2 060		10 480		13 490		8.0		18.0		91.0		117.0	
116	Total above Augusta,		5 927		32 620		33 230		15 660		81 510		5.5		5.6		2.7		13.8
122	Cobbosseecontee River,	230		5 470		3 070		0		8 540		21.0		13.0		0		37.0	
	Between Augusta and Merrymeeting Bay,†	201		1 840		7 940		10 690		20 470		9.0		39.0		53.0		101.0	
141	Total above mouth of Kennebec River,		6 358		39 930		41 240		26 350		110 520		6.3		6.9		4.1		17.3

* Omitting the Messalonskee and Sebasticook.

† Omitting the Cobbosseecontee.

Classification of population:
- Rural, communities with less than 1 000 inhabitants.
- Village, communities with between 1 000 and 4 000 inhabitants.
- Urban, communities with more than 4 000 inhabitants.

TABLE No. 2.—SEWAGE AND MANUFACTURING WASTES DISCHARGED INTO THE KENNEBEC AND SEBASTICOOK ABOVE THE INTAKE OF THE AUGUSTA WATER COMPANY.

Sources of Pollution.	Miles above Intake.	Persons using Public Sewers.	Persons in Mills.	Persons using Privies or Private Sewers.	MANUFACTURING WASTES.* Quantities Discharged Daily. Woolen Mills. Spent Dye. Gals.	Woolen Mills. Preparatory Liquor. Gals.	Woolen Mills. Soap. Lbs.	Woolen Mills. Wash Water. Gals.	Paper and Pulp Mills. Ground Wood Wash. Gals.	Paper and Pulp Mills. Sulphite Wash. Gals.	Paper and Pulp Mills. Paper Machine. Gals.	Paper and Pulp Mills. Spent Sulphite Liquor. Gals.
WATERVILLE	17.1	3 372										
Lockwood Mfg. Co.			1 300									
Riverview Worsted Co.			250		10 000		600	30 000				
Waterville Iron Works				30								
Colby University				88								
Maine Central Round House			100									
Maine Central Car Shops			295									
Chase Mfg. Co.			65		750		30					
A. P. Emery												
Hayden Brook				36								
WINSLOW												
Hollingsworth & Whitney Co.			650						3 000 000	2 000 000	250 000	140 000
FAIRFIELD	20.6											
Fairfield Furniture Co.			35									
Grist Mill			1									
Electric Power Station			5									
United Box B'd & Paper Co.			13									
American Woolen Co.			175		5 000	5 000	80					
			80									
SHAWMUT												
United Box B'd & Paper Co.	23.8											
Lawrence Newhall & Page Co.			210						200 000			

SKOWHEGAN	31	1 516		140								
American Woolen Co.			175		10 000	10 000	310	30 000				
Marston Worsted Co.			275		6 000		75	40 000				
Com'wealth Shoe & L'th'r Co.			250									
Bowdoin Pulp Co.			10									
Skowhegan Pulp Co.			25						50 000			
Electric Light Co.			5									
Currier Brook				39								
MADISON	16	636										
Madison Woolen Co.			200		7 000		300					
Indian Spring Woolen Co.			200		5 000	5 000	150					
Great Northern Paper Co.										1 500 000	1 500 000	120 000
NORTH VASSALBORO	21.1											
American Woolen Co.			300		6 000	2 000	500					
BENTON FALLS	21.8											
United Box B'd & Paper Co.			100									
PITTSFIELD	41	1 500										
Pittsfield El. L't & Power Co.			46									
R. Dobson & Co.			300		1 500	1 500						
Waverly Woolen Co.			175		4 500	7 000	250					
Riverside Woolen Co.			110		600		125					
NEWPORT	44.5	442		4								
Newport Woolen Co.			150		5 000	5 000	250					
Weymouth Wool Co.			45									
Borden Condensed Milk Co.			30									
Total		7 466	5 608	337	61 350	35 500	2 700	100 000	3 250 000	3 500 000	1 750 000	260 000

* Data incomplete.

TABLE No. 3.—NUMBER OF DEATHS FROM TYPHOID FEVER IN WATERVILLE, ME., FROM 1892 TO 1903 BY MONTHS.

MONTHS.	1892.	1893.	1894	1895	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	Total.
January . .	0	1	0	0	0	0	1	0	0	1	0	8	11
February .	0	1	0	0	0	1	0	0	0	0	0	5	7
March	0	2	0	0	0	0	1	0	0	1	0	3	7
April	0	0	0	0	0	0	0	1	0	0	0	0	1
May	0	0	0	0	0	0	0	0	0	0	0	1	1
June	0	0	1	0	0	0	0	0	0	0	0	0	1
July	0	0	0	0	0	0	0	1	0	0	1	1	3
August . . .	0	0	0	0	0	0	0	1	1	2	0	—	4*
September	1	0	0	1	0	2	0	1	0	1	2	—	8*
October . .	0	0	0	0	0	0	0	0	0	1	2	—	3*
November.	0	0	1	0	0	0	0	0	0	1	1	—	3*
December.	0	0	1	0	0	0	0	0	1	1	2	—	5*
Total. . .	1	4	3	1	0	3	2	4	2	8	8	18	36*

* Total for 1892 to 1902.

TABLE No. 4.—NUMBER OF CASES OF TYPHOID FEVER IN EACH MONTH FROM JANUARY 1, 1902, TO AUGUST 1, 1903, IN WATERVILLE, FAIRFIELD, WINSLOW, AND BENTON.

MONTH.	Waterville.	Fairfield.	Winslow.	Benton.	Total.
1902, January	2	0	0	0	2
February	1	1	0	0	2
March	4	0	0	0	4
April	3	0	0	0	3
May	3	0	0	0	3
June	4	0	1	0	5
July	13	1	1	0	15
August	12	1	2	1	16
September	10	1	1	0	12
October	7	3	1	0	11
November.	20	5	2	0	27
December	64	6	14	1	85
1903, January	89	25	10	1	125
February	23	8	7	0	38
March	11	3	0	0	14
April	5	1	1	0	7
May	0	1	1	0	2
June	0	0	0	0	0
July	0	0	0	0	0
Total	271	56	41	3	371

TABLE No. 5.— AGES OF TYPHOID FEVER PATIENTS IN WATERVILLE, FAIRFIELD, WINSLOW, AND BENTON, ME.

	Sex.	0–4.	5–9.	10–14	15–19.	20–24.	25–29.	30–34	35–39.	40–44.	45–49.	50–59.	Over 60.	Not Given.	Total.
Waterville,	Male,	4	16	23	23	27	12	9	6	2	2	3	1	3	131
	Female,	5	22	30	24	26	8	5	6	3	5	4	1	1	140
	Total,	9	38	53	47	53	20	14	12	5	7	7	2	4	271
Fairfield,	Male,	0	4	8	3	2	1	2	1	0	0	0	0	0	21
	Female,	2	6	11	3	5	1	0	2	1	0	1	3	0	35
	Total,	2	10	19	6	7	2	2	3	1	0	1	3	0	56
Winslow,	Male,	0	2	6	3	4	3	4	0	1	0	2	0	1	26
	Female,	1	2	2	2	4	1	0	0	0	0	1	1	1	15
	Total,	1	4	8	5	8	4	4	0	1	0	3	1	2	41
Benton,	Male,	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	Female,	0	0	0	1	1	0	0	0	0	0	0	0	0	2
	Total,	0	0	1	1	1	0	0	0	0	0	0	0	0	3
Total,	Male,	4	22	38	29	33	16	15	7	3	2	5	1	4	179
	Female,	8	30	43	30	36	10	5	8	4	5	6	5	2	192
	Total,	12	52	81	59	69	26	20	15	7	7	11	6	6	371

TABLE No. 6.— ABSENCE FROM CITY OF THE TYPHOID FEVER PATIENTS DURING FOUR WEEKS PREVIOUS TO ILLNESS.

	Absent.	Not Absent.	Not Stated.	Total.
Waterville	8	253	10	271
Fairfield	0	56	0	56
Winslow	0	40	1	41
Benton	0	3	0	3
Total	8*	352	11	371

* 2.2% of total cases.

TABLE No. 7.—Occupations of the Typhoid Fever Patients in Waterville, Fairfield, Winslow, and Benton.

Occupation.	Sex.	Waterville.	Fairfield.	Winslow.	Benton.	Total.
Students,	Male	31	9	3	1	44
	Female	35	12	1	1	49
	Total,	66	21	4	2	93
Mill Hands,	Male,	35	6	15	0	56
	Female,	25	1	6	0	32
	Total,	60	7	21	0	88
Housekeepers and Servants,	Female,	31	6	4	1	42
Clerks,	Male,	12	0	0	0	12
	Female,	10	1	0	0	11
	Total,	22	1	0	0	23
Car Shop Employees,	Male,	12	1	1	0	14
Laborers,	Male,	10	1	2	0	13
Professional Men,	Male,	3	0	0	0	3
Artisans,	Male,	8	0	0	0	8
	Female,	0	1	0	0	1
	Total,	8	1	0	0	9
Not Stated,	Male,	20	4	5	0	29
	Female,	39	14	4	0	57
	Total,	59	18	9	0	86
Total,	Male,	131	21	26	1	179
	Female,	140	35	15	2	192
	Total,	271	56	41	3	371

TABLE No. 8.* — Results of a House-to-House Canvass in Waterville, Me., with Reference to the Character of the Water Supplies, and the Number of Cases of Typhoid Fever.

Water Supply at Residence.	Number of Persons.	Number of Typhoid Cases.	Morbidity Rate per 1 000.
Maine Water Company	6 537	226	34.6
Maine Water Company and no other supply	3 225	132	40.9
Maine Water Company and well water	866	23	26.6
Maine Water Company and spring water	2 424	71	29.3
Maine Water Company and cistern water	2	0	0.0
Maine Water Company, spring water, and well water	20	0	0.0
Maine Water Company and well, spring, or cistern water	3 312	91	28.4
Supplies other than Maine Water Company	1 459	21	14.4
Well water only	1 286	19	14.8
Well water and spring water	25	1	40.0
Well water and cistern water	13	0	0.0
Spring water only	108	1	9.3
Spring water and cistern water	23	0	0.0
Cistern water only	4	0	0.0
Total	7 996	247	30.9

* Similar tables were made for Winslow, Fairfield, and Benton.

TABLE No. 9. — Summary of a House-to-House Canvass in the Kennebec Water District, with Reference to the Character of the Water Supplies and the Number of Cases of Typhoid Fever.

	Supply from Maine Water Company.			No Supply from Maine Water Company.			Total.		
	Number of Persons.	Number of Typhoid Cases.	Morbidity Rate per 1 000.	Number of Persons.	Number of Typhoid Cases.	Morbidity Rate per 1 000.	Number of Persons.	Number of Typhoid Cases.	Morbidity Rate per 1 000.
Waterville	6 537	226	34.57	1 459	21	14.41	7 996	247	30.9
Fairfield	1 614	54	33.45	468	2	4.25	2 082	56	26.9
Winslow	244	11	45.08	902 (470)*	19 (4)*	21.06 (8.29)*	1 146	30	26.2
Benton	152	2	13.15	125	1	8.00	277	3	10.8
Total	8 547	293	34.28	2 954	43	14.55	11 501	336	29.2

* Omitting users of Kennebec River water.

TABLE No. 10. — STATISTICS OF POPULATION AND TYPHOID FEVER FOR AUGUSTA, ME., FROM 1865 TO 1903. (FROM RECORDS IN THE CITY CLERK'S OFFICE.)

Year.	Population Estimated.	Deaths.		Death Rate per 100 000.		Typhoid per cent. of Total Deaths.
		Total.	Typhoid.	Total.	Typhoid.	
1865	7 650	90	12	1 176.0	156.9	13.3
1866	7 675	26	1	338.8	130.0	3.9
1867	7 700	3	0	39.0	0.0	0.0
1868	7 750	1	0	12.9	0.0	0.0
1869	7 800	50	3	641.0	38.5	6.0
1870	7 808	99	4	1 268.0	51.2	4.1
1871	7 875	90	2	1 143.0	25.40	2.2
1872	7 925	95	6	1 198.0	75.7	6.3
1873	8 000	138	4	1 725.0	50.0	2.9
1874	8 075	80	0	991.0	0.0	0.0
1875	8 150	90	0	1 104.0	0.0	0.0
1876	8 225	131	6	1 584.0	73.0	4.6
1877	8 300	125	6	1 505.0	72.3	4.8
1878	8 425	128	6	1 520.0	71.2	4.7
1879	8 550	101	1	1 182.0	11.7	0.99
1880	8 445	115	0	1 327.0	0.0	0.0
1881	8 665	131	4	1 185.0	45.3	3.1
1882	9 000	102	1	1 134.0	11.1	0.98
1883	9 175	127	2	1 384.0	21.8	1.6
1884	9 400	80	0	851.0	0.0	0.0
1885	9 575	100	1	1 044.0	10.4	1.0
1886	9 775	143	6	1 462.0	61.4	4.2
1887	9 995	170	8	1 704.0	80.2	4.7
1888	10 175	151	4	1 484.0	39.3	2.7
1889	10 350	139	2	1 343.0	19.3	1.4
1890	10 527	182	16	1 729.0	152.0	8.8
1891	10 675	34	5	318.0	46.9	14.7
1892	10 825	315	7	2 910.0	64.7	2.2
1893	10 950	304	9	2 776.0	82.2	3.0
1894	11 075	322	6	2 906.0	54.2	1.9
1895	11 200	322	7	2 874.0	62.5	2.2
1896	11 325	316	11	2 790.0	97.1	3.5
1897	11 425	323	7	2 825.0	61.2	2.2
1898	11 525	257	20	2 230.0	173.5	7.8
1899	11 625	318	9	2 734.0	77.4	2.8
1900	11 683	289	4	2 472.0	34.2	1.4
1901	11 800	312	11	2 644.0	93.2	3.5
1902	11 875	304	6	2 560.0	50.3	2.0
1903	11 975	297	31	2 480.0	25.9	10.4

TABLE No. 11. — TYPHOID FEVER DEATHS IN AUGUSTA, ME. BY MONTHS FROM 1865 TO 1903.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1865	0	0	0	1	0	0	0	4	3	4	0	0
1866	1	0	0	0	0	0	0	0	0	0	0	0
1867	0	0	0	0	0	0	0	0	0	0	0	0
1868	0	0	0	0	0	0	0	0	0	0	0	0
1869	0	0	1	0	0	0	0	1	0	1	0	0
1870	0	0	0	0	0	0	1	1	0	2	0	0
1871	0	0	0	0	0	0	0	0	1	0	1	0
1872	0	0	0	0	0	1	0	0	1	3	1	0
1873	0	0	0	0	0	0	1	0	2	0	0	1
1874	0	0	0	0	0	0	0	0	0	0	0	0
1875	0	0	0	0	0	0	0	0	0	0	0	0
1876	0	0	0	0	1	2	1	0	1	0	1	0
1877	0	0	0	0	0	0	0	2	0	4	0	0
1878	0	0	0	0	0	0	1	0	0	2	0	3
1879	1	0	0	0	0	0	0	0	0	0	0	0
1880	0	0	0	0	0	0	0	0	0	0	0	0
1881	0	0	0	0	0	1	0	0	0	2	1	0
1882	0	0	1	0	0	0	0	0	0	0	0	0
1883	0	0	1	0	0	0	0	0	0	1	0	0
1884	0	0	0	0	0	0	0	0	0	0	0	0
1885	0	0	0	0	0	0	1	0	0	0	0	0
1886	0	0	1	0	1	0	0	1	0	1	2	0
1887	0	0	0	0	1	0	0	1	3	3	0	0
1888	1	1	0	0	0	0	0	0	0	2	0	0
1889	0	0	0	1	0	0	0	0	0	1	0	0
1890	2	0	0	1	0	1	2	1	3	1	1	4
1891	0	4	1	0	0	0	0	0	0	0	0	0
1892	0	0	1	1	1	0	0	0	0	1	1	2
1893	1	1	5	0	0	0	0	0	0	1	1	0
1894	1	1	2	0	0	0	0	0	0	0	0	2
1895	0	2	1	0	0	0	0	0	0	1	0	3
1896	0	3	0	3	1	0	0	0	0	1	1	2
1897	0	0	4	1	1	0	0	0	0	0	0	1
1898	0	2	1	1	1	0	0	0	10	3	1	1
1899	1	2	0	1	0	1	0	0	0	1	2	1
1900	0	0	0	0	0	0	0	0	2	0	0	2
1901	1	1	2	2	1	1	0	0	0	0	2	1
1902	1	0	1	0	0	1	1	0	0	1	0	1
1903	7	8	10	4	1	0	1	0	0	0	0	0

TABLE No. 12. — CHRONOLOGICAL TABLE OF TYPHOID CASES AND DEATHS IN AUGUSTA BETWEEN OCTOBER 1, 1902, AND MAY 1, 1903.

DATE.	October.	November.	December.	January.	February.	March.	April.
1	0	0	1	3	5 + 1*	1 + 1* + 1†	2
2	0	2 + 1†	1	2 + 1*	1	2 + 1*	2 + 1*
3	0	0	1	3	1	2 + 1*	0
4	0	0	1	0	1 + 1* + 1†	1	1
5	0	0	1 + 1*	1*	5 + 2*	2	0
6	0	0	2 + 1†	2	4 + 3*	1	0
7	0	0	0	1	3	2 + 1*	0
8	0	0	0	0	5 + 1*	1	0
9	0	0	1	2	4 + 1*	4	1
10	0	0	1	1	2	1	0
11	0	0	2	0	2	0	0
12	0	0	2	4	3 + 1*	3	0
13	0	0	1	0	1	0	0
14	0	1	1	3	5 + 1*	2	0
15	0	1	0	3	1	0	0
16	0	1	1	2	3 + 1*	1	0
17	0	0	1	6 + 3*	3	1	2
18	0	0	1*	3	6 + 1*	1	0
19	0	0	1	3	1†	0	0
20	0	0	1	2	11 + 1*	1 + 1*	0
21	1*	1	2	0	5 + 1*	0	0
22	0	1	3	5 + 1*	2	1	0
23	0	0	1*	3	2	3	0
24	0	1	1	2 + 1*	4	1	0
25	0	3	0	6	3	0	0
26	0	2	1	2	2	1	1
27	0	0	0	1	0	2	1
28	0	0	0	2	3	1	0
29	1	1*	3	2	0	0	0
30	0	0	1	2	0	1	0
31	0	0	1	0	0	1	0
Totals	2–1*	15–1*	35–3*	72–7*	104–15*	43–5*	11–1*

* Indicates deaths. † Indicates date of case is uncertain.

Total for epidemic of 1902–1903, 280, November 1, 1902, to May 1, 1903.

TABLE No. 13. — SEASONAL DISTRIBUTION OF TYPHOID FEVER IN AUGUSTA, ME., BEFORE AND AFTER THE INTRODUCTION OF KENNEBEC RIVER WATER. (COMPILED FROM RECORDS IN THE CITY CLERK'S OFFICE.)

	Period.	Average Population.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Number of Deaths	1865–1887	8 200	2	0	4	1	3	4	5	10	11	23	6	4
	1888–1903	11 300	15	25	28	15	6	4	4	1	15	13	9	20
Death Rate per 100 000	1865–1887	8 200	1.06	0	2.12	0.53	1.59	2.12	2.65	5.30	5.83	12.21	3.18	2.12
	1888–1903	11 300	8.32	13.80	15.50	8.87	3.33	2.20	2.20	0.55	8.32	7.18	4.98	11.07

TABLE No. 14. — SHOWING DISTRIBUTION OF TYPHOID IN AUGUSTA, ME., BY AGES AND SEX, JANUARY 1, 1902, TO JANUARY 1, 1904.

Age.	Cases.		Deaths.	
	Male.	Female.	Male.	Female.
0 — 4	7	6	1	2
5 — 9	21	20	1	0
10 — 14	25	28	0	2
15 — 19	31	26	4	3
20 — 24	30	33	3	1
25 — 29	27	20	2	2
30 — 34	7	3	3	0
35 — 39	8	12	0	4
40 — 44	7	7	1	1
45 — 49	3	7	1	1
50 — 54	2	2	0	0
55 — 59	1	1	4	0
60 — 64	0	0	0	0
65 — 69	1	0	1	0
70 and up	1	0	0	0
Total	171	165	18	16

Total cases, 336; total deaths, 34.

TABLE No. 15. — SHOWING DISTRIBUTION OF TYPHOID IN AUGUSTA, ME., BY OCCUPATION, JANUARY 1, 1902, TO JANUARY 1, 1904.

Occupation.	Male.	Female.	Total.
Students	43	50	93
Mill hands	25	28	53
Clerks	15	11	26
Laborers	24	2	26
Artisans	28	3	31
Professional men	4	7	11
Railroad employees	4	0	4
Business men	5	0	5
Lunatics	2	0	2
Children	12	11	23
Servants	2	5	7
Housekeepers	0	23	23
Not stated	8	24	32
Total	172	164	336

TABLE No. 16. — STATISTICS OF DISINFECTION OF STOOLS, AND ABSENCE FROM CITY DURING MONTH PREVIOUS TO SICKNESS. COMPILED FOR TYPHOID CASES FROM JANUARY 1, 1902, TO JANUARY 1, 1904, AUGUSTA, ME.

DISINFECTION OF STOOLS.

Number of Cases.		
Stool Disinfected.	Stools not Disinfected.	Not Stated.
262	48	26

ABSENCE FROM CITY.

Number of Cases.		
Not Absent.	Absent.	Not Stated.
308	22	6

TABLE No. 17. — WATER CANVASS. TABLES SHOWING THE DISTRIBUTION OF TYPHOID FEVER IN THE CITY OF AUGUSTA ACCORDING TO WATER SERVICE IN 1903.

JANUARY 1, 1902, TO JANUARY 1, 1904.

WATER SUPPLY USED.	Number of Persons.	Typhoid Cases.	Typhoid Deaths.	Morbidity per 1 000.
River only	2 980	160	16	53.7
Devine only	408	5	1	12.3
Wells, springs, and cisterns	1 441	34	5	23.6
River and Devine	295	7	2	23.7
River and wells, springs, and cisterns	3 671	105	6	28.6
Devine and springs or cisterns	39	0	0	0
Unclassified	12	0	0	0
Total	8 846	311	30	35.2

DURING THE EPIDEMIC, NOVEMBER 1, 1902, TO MAY 1, 1903.

WATER SUPPLY USED.	Number of Persons.	Typhoid Cases.	Typhoid Deaths.	Morbidity per 1 000.
River only	2 980	134	15	45.0
Devine only	408	3	1	7.3
Wells, springs, and cisterns	1 441	28	5	19.4
River and Devine	295	7	2	23.7
River and wells, springs, and cisterns	3 671	88	6	24.0
Devine and springs or cisterns	39	0	0	0
Unclassified	12	0	0	0
Total	8 846	260	29	29.4

TABLE No. 18. — POPULATIONS, NUMBER OF DEATHS FROM TYPHOID FEVER, AND THE AVERAGE TYPHOID FEVER DEATH RATES FOR CITIES AND TOWNS IN THE STATE OF MAINE WHICH HAVE MORE THAN 4 000 INHABITANTS, FROM 1892 TO 1903. COMPILED FROM THE PUBLIC REPORTS OF THE STATE BOARD OF HEALTH.

County.	City or Town.	Population.		Number of Typhoid Deaths Each Year.												Total No. of Typhoid Deaths.	Average Death Rate per 100 000
		1890.	1900.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.		
Kennebec,	Augusta,	10 527	11 683	9	7	6	5	5	5	19	8	4	9	4	29	110	79
York,	Saco,	6 075	6 122	4	1	1	6	9	3	3	4	6	5	4	5	51	70
York,	Biddeford,	14 443	16 145	18	5	4	12	17	8	6	5	16	19	10	8	128	66
Androscoggin,	Lewiston,	21 701	23 761	36	13	21	9	11	14	17	24	15	13	2	3	178	62
Penobscot,	Bangor,	19 103	21 850	21	12	25	13	8	8	7	15	4	24	7	10	154	59
York,	Sanford,	4 201	6 078	1	4	1	1	2	2	1	3	1	0	17	9	42	58
Cumberland,	Brunswick,	6 012	6 806	15	9	7	6	0	0	1	2	1	2	0	3	46	57
Penobscot,	Oldtown,	5 312	5 763	4	1	3	2	2	1	3	2	3	7	0	9	37	53
Aroostook,	Caribou,	4 087	4 758	1	1	6	2	5	0	3	3	4	2	1	0	28	49
Hancock,	Ellsworth,	4 804	4 297	1	2	4	0	2	5	3	0	2	0	2	2	23	45
Kennebec,	Waterville,	7 107	9 477	2	3	3	1	0	3	2	3	2	7	7	17	50	44
Penobscot,	Brewer,	4 193	4 835	0	3	6	0	2	1	0	4	1	7	1	0	25	43
Washington,	Calais,	7 290	7 655	0	9	5	0	7	0	0	4	2	3	3	2	35	38
Aroostook,	Ft. Fairfield,	3 526	4 181	2	0	2	9	2	0	0	2	0	0	0	0	17	34
Cumberland,	Portland,	36 425	50 145	6	14	20	21	12	11	36	13	19	15	15	17	199	33
Aroostook,	Houlton,	4 015	4 686	0	3	1	1	1	1	0	3	2	0	2	3	17	30
Cumberland,	Westbrook,	6 632	7 283	1	3	2	3	2	0	4	2	1	1	2	3	24	27
Washington,	Eastport,	4 908	5 311	0	2	2	3	0	1	3	1	0	2	1	1	16	25
Cumberland,	S. Portland,		6 287				0	3	5	0	2	0	0	1	3	14	25
Hancock,	Eden,	1 946	4 379	1	1	0	0	1	2	0	2	3	0	1	0	11	21
Androscoggin,	Auburn,	11 250	12 951	3	6	3	1	5	1	3	5	4	0	1	1	33	21
Kennebec,	Gardiner,	5 491	5 501	0	2	0	0	1	2	2	2	1	2	1	1	14	21
Knox,	Rockland,	8 174	8 150	3	4	0	2	0	1	5	1	1	1	1	1	20	20
Somerset,	Belfast,	5 294	4 615	1	3	0	1	1	0	1	1	0	0	0	1	9	17
Sagadahoc,	Bath,	8 723	10 477	2	3	2	1	2	0	1	0	1	1	2	1	16	13
Somerset,	Skowhegan,	5 068	5 180	2	1	1	2	0	0	0	1	0	0	0	0	7	11

TABLE No. 19. — Populations, Number of Deaths from Typhoid Fever, and the Average Typhoid Fever Death Rates for Cities and Towns in the State of Maine which have between 2 000 and 4 000 Inhabitants, from 1892 to 1903.

County.	City or Town.	Population.		Number of Typhoid Deaths in Each Year.												Total No. of Typhoid Deaths.	Average Death Rate per 100 000.
		1890.	1900.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.		
Oxford,	Rumford,	898	3 770	2	5	0	1	2	1	2	1	3	3	5	3	28	62
Kennebec,	Winslow,	1 814	2 277	2	3	0	0	0	3	0	1	0	0	2	5	16	59
Penobscot,	Hampden,	2 484	2 182	1	1	1	3	0	0	1	1	3	1	0	0	12	46
Kennebec,	Hallowell,	3 181	2 714	0	1	2	1	2	1	1	0	0	4	2	1	15	46
Androscoggin,	Lisbon,	3 120	3 603	3	6	1	0	1	0	1	6	1	0	0	0	19	44
York,	Kittery,	2 864	2 878	4	0	3	0	0	0	0	0	1	3	2	2	15	44
Somerset,	Pittsfield,	2 503	2 891	0	0	1	3	2	0	2	3	1	1	1	1	15	43
Penobscot,	Orono,	2 790	3 257	2	3	1	1	1	0	0	0	0	2	5	1	16	41
York,	So. Berwick,	3 434	3 188	2	1	1	2	4	0	2	1	0	0	2	0	15	39
Franklin,	Jay,	1 541	2 758	1	0	0	4	1	1	1	1	1	0	0	1	11	33
Franklin,	Farmington,	3 207	3 288	0	3	2	3	1	1	1	1	0	0	0	1	13	33
Hancock,	Bucksport,	2 921	2 339	1	3	2	0	0	0	1	0	0	1	1	0	9	32
Aroostook,	Presque Isle,	3 046	3 804	6	4	2	1	0	0	0	0	1	2	1	0	17	31
Sagadahoc,	Richmond,	3 082	2 049	1	0	2	0	0	0	1	0	2	1	1	1	9	31
Hancock,	Deer Isle,	3 422	2 047	2	1	3	1	0	1	0	0	0	0	0	1	9	31
Aroostook,	Fort Kent,	1 826	2 528	0	0	0	0	2	0	0	4	0	0	1	1	9	30
Somerset,	Fairfield,	3 510	3 878	0	2	1	0	0	2	0	1	0	1	1	6	14	30
Kennebec,	Vassalboro,	2 052	2 062	0	0	0	2	2	0	0	0	1	0	2	1	8	28
Androscoggin,	E. Livermore,	1 506	2 129	0	4	0	0	0	2	0	1	0	0	0	0	7	28
Oxford,	Paris,	3 156	3 225	3	0	0	0	1	2	0	1	2	1	0	0	10	26
York,	Berwick,	2 294	2 280	1	0	0	1	1	0	1	0	2	0	1	0	7	26
Washington,	Lubec,	2 069	3 005	0	0	3	2	0	0	0	2	2	0	0	0	9	25
York,	Wells,	2 029	2 007	2	1	0	0	0	0	1	0	0	1	0	1	6	25
Knox,	Thomaston,	3 009	2 688	1	2	1	0	2	0	0	0	0	0	2	0	8	25
York,	Kenneb'kp't,	2 196	2 123	1	0	1	1	0	0	0	0	1	0	1	1	6	24
Lincoln,	Waldoboro,	3 505	3 143	0	0	1	0	0	2	1	0	1	1	1	2	9	24
Lincoln,	Bristol,	2 821	2 572	1	0	0	2	0	1	1	1	0	1	0	0	7	23
Knox,	Rockport,	2 150	2 314	0	0	0	0	0	0	1	1	1	2	0	1	6	22
York,	Kennebunk,	3 172	3 228	0	1	3	1	1	0	2	0	0	0	0	0	8	21
Washington,	Jonesport,	1 917	2 124	0	0	1	2	0	0	0	0	1	1	0	0	5	20
Penobscot,	Dexter,	2 732	2 941	2	0	2	1	0	0	1	0	0	1	0	0	7	20
Cumberland,	Gorham,	2 888	2 540	0	0	0	0	1	1	2	0	1	0	0	1	6	20
Sagadahoc,	Topsham,	1 394	2 097	1	1	0	0	1	0	1	0	0	0	0	0	4	16
Somerset,	Madison,	1 815	2 764	1	1	1	0	0	0	0	0	1	1	0	0	5	15
Kennebec,	Winthrop,	2 111	2 088	0	1	0	0	0	0	0	1	0	0	1	1	4	16
Knox,	Warren,	2 037	2 069	0	1	0	1	0	0	1	0	0	0	0	0	3	12
Knox,	Camden,	2 471	2 825	0	0	0	0	0	0	0	0	0	2	1	1	4	12
Oxford,	Norway,	2 665	2 902	0	1	1	0	0	1	1	0	0	0	0	0	4	11
Cumberland,	Freeport,	2 482	2 339	1	1	0	0	0	1	0	0	0	0	0	0	3	11
Cumberland,	Yarmouth,	2 098	2 274	0	1	1	0	0	0	0	0	0	0	0	1	3	11
Cumberland,	Bridgton,	2 605	2 868	1	0	1	0	1	0	0	0	0	0	0	0	3	9
Knox,	St. George,	2 491	2 206	0	0	0	0	0	0	1	0	1	0	0	0	2	8
Knox,	Vinalhaven,	2 617	2 358	0	0	0	1	0	0	0	1	0	0	0	0	2	7
Kennebec,	Chelsea,	2 356	3 092	0	0	1	0	0	0	1	0	0	0	0	0	2	5
Hancock,	Tremont,	2 036	2 010	0	0	0	0	0	1	0	0	0	0	0	0	1	4
Washington,	Machias,	2 035	2 082	0	0	0	0	0	0	0	0	1	0	0	0	1	4
York,	York,	2 444	2 668	0	0	0	0	0	0	0	0	0	1	0	0	1	4

DISCUSSION.

MR. CHARLES G. HYDE. I want to express my appreciation and thanks to the gentlemen who prepared the paper just read. The investigations carried on by them were thorough and eminently scientific. I am very glad that such an excellent report of this study has been presented to this Association, so that it can be published. I do not believe that many of us realize the great educational value that these papers have as they go out among sanitarians, engineers, and water-works men generally.

Every year adds to our knowledge (a vast amount having been already accumulated) of the intimate association between the quality of the water supply and the health of the communities supplied. You in Massachusetts are very fortunate in having a state board of health, the pioneer in all this work, which has been able to study the quality of the water supplies of this state for a very long time, so that there is hardly a supply whose character is not now known. Those of you who live in this commonwealth are able to know how comparatively safe you are in taking a glass of water.

I am less fortunate than many of you in that I am living in a state where very little public attention is paid to the quality of the water. I have been living in Pennsylvania for the last four years, and since residing in Harrisburg, I think I have not taken a glass of raw water at any time. All water used for drinking in our house has to be first filtered and then boiled, and even then we have some difficulty in getting good results, because the water is so very bad to start with. Until I went to Harrisburg nothing at all was known in regard to the quality of the Susquehanna River water. It is the largest stream entering the Atlantic Ocean between the Gulf of St. Lawrence and the Gulf of Mexico; notwithstanding that fact, however, I believe very few analyses of the water have been made either in New York or Pennsylvania or to the south. In taking up the question of the purification of the water supply of Harrisburg, it was necessary to start at the beginning and install a laboratory to discover what the real character of the water was, and to equip an experimental purification plant to see how it could best be improved. That

work has been done. No paper embodying the results of the investigations has been as yet published, but I hope one may be soon.

The typhoid fever death rate in communities along the Susquehanna River, where the unpurified water is used, is high; it has been continuously high for a great many years, and is likely to be so in the future, because very few of these towns, except Harrisburg and one or two others, are considering the quality of the water which they use for drinking.

A great deal of information has been gathered in regard to the immediate relation between the quality of drinking water and the health of communities. Dr. Sedgwick, for instance, in his recent Lowell Institute course of lectures, has shown how the health of the city of Lawrence has been improved — not only as regards typhoid fever, but in general — by the filtering of the public water supply. These same facts were exhibited by Mr. Morris Knowles and myself in a paper presented two or three years ago to the American Society of Civil Engineers in New York. The results are really marvellous, and they simply show how important this question is. A study of the effect of the Albany filters upon the typhoid fever and the general death rate in that city reveals the same most satisfactory results. And I have reason to believe that the data collected with regard to this point in many other places present the same features.

There is just one thing more that I should like to say, and that is, that I think water-works officials and engineers should act in harmony with the officials of health boards, not only the state boards in the several commonwealths, but the local boards of health. I think every one of us should look forward to the time when infectious diseases of every nature, and especially those which are water borne, shall be accurately, systematically, and thoroughly reported, and the records carefully studied by the public at large, so that these epidemics which have been such an enormous drain, not only upon the health but upon resources of the communities in which they have occurred, shall be avoided, and we shall truly live in an era of very much better health.

Mr. Charles-Edward A. Winslow. Truth is said to be

at the bottom of a well. I suppose for that reason it is natural that when you get to the bottom of any water-works proposition you find some pretty big fundamental truths.

It seems to me that in this discussion to-day we have been getting down to some principles which have a much wider application than to the matter of water supply alone. In the course of lectures to which Mr. Hyde just referred, Professor Sedgwick said a word or two in regard to the extension of public powers in its bearing on public health. Now this question of public ownership, or Socialism, is perhaps the most important political question that we have to face in the next twenty years. Professor Sedgwick said that there are always a great many people who say, "It is a good thing to have gone as far as we have gone, but we do not want to go any farther," and he pointed out that that is not the way the world works; if it sets out on a certain path it is likely to keep going on. I think we have all, as citizens, to meet the probability that Socialism, merely defined as the extension of the power of the state, is going to increase, and it is very necessary that we should see that it increases along sound and wise lines.

In Massachusetts we are pretty familiar with extreme Socialism in the matter of water-works control. In other states the problem is being met in different ways, sometimes, as has been stated, by contracts with water companies. In Louisville they have met it by the city gradually acquiring the stock of the water company, which I think is held by the sinking fund commissioners, just as any other city property is held. And we have heard to-day of a new and an extremely interesting and important method of gaining control by the municipality.

Professor Smith has brought out the point that the administration of the private company is often admirable, better than that of the municipality. But isn't this so largely because those water companies know that if they do not come very sharply up to the mark, the city will step in and take their franchises? So that even in those cases we can say that the good quality of the water supply is due to the potential control of the city. Is not that a good general principle, that as long as private companies perform public functions well and cheaply, they may continue to do so,

and as soon as they cease to do this, the public must step in and take control?

When this happens I submit that the two admirable papers we have heard read to-day furnish valuable precedents as to the way in which the public should proceed.

The extension of the power of the state should not be made rashly or unadvisedly; but when it is made, as in the case of these Maine water districts, by a strictly legal method and after the most thorough investigation by competent experts, the socialization of public utilities may be one of the most efficient aids to social progress.

Mr. Langdon Pearse* (by letter). In this paper Messrs. Whipple and Levy have succinctly stated the main points of the recent typhoid epidemic in the Kennebec River valley. The writer, however, would like to add a few notes of interest, as he was the resident sanitary engineer for Mr. Whipple at Augusta.

The two principal towns above Fairfield, on the Kennebec, are Skowhegan and Madison. Both towns are partly sewered into the Kennebec. They are supplied with a water which seems fairly safe at present. Skowhegan is supplied by several aqueducts from springs and by water pumped from a pond below the town. At times of drought this supply is re-inforced by pumping river water. Madison draws its supply from the Kennebec above the dam below which its sewage is discharged. Above Madison there is no town which discharges sewers into the Kennebec.

In order to supplement the published typhoid records, the writer, in the course of an inspection trip, interviewed a number of physicians in both Madison and Skowhegan, and found that the typhoid occurred only in scattering cases, and then, as a rule, in the spring and fall, the normal season for typhoid.

On the Sebasticook, a tributary of the Kennebec, the two towns with sewers are Pittsfield and Newport. Pittsfield derives its water supply from the west branch of the Sebasticook, Newport from a pond. In neither town has there been much typhoid. Most of the cases have occurred in the spring and fall, though in Pittsfield there are more in the winter than in Newport. So

* Draughtsman on Purification of Water Supply, Board of Public Service, Columbus, Ohio.

far as I could ascertain, none of these towns had ever suffered from a typhoid epidemic. This information, in connection with the low typhoid death rate at Hallowell and Gardiner, and the few cases there traceable, shows the comparative immunity from typhoid enjoyed by those communities in the Kennebec valley which use a water supply unlikely to be infected or polluted. It also gives another reason why it is probable that the direct source of the past typhoid epidemics at Augusta has been the sewage of Oakland and Waterville.

In the following table I have shown the annual typhoid deaths (taken from the reports of the Maine State Board of Health) and the average typhoid death rate for the principal towns on the Kennebec watershed. This table is, I think, self-explanatory. I would call attention to the fact that many of the deaths noted for Madison, Skowhegan, Pittsfield, and Newport did not occur at the same season as those in Waterville or Augusta.

TABLE No. 20.

DEATHS FROM TYPHOID FEVER IN THE PRINCIPAL TOWNS IN THE KENNEBEC VALLEY 1892–1903.

Town.	Population, U. S. Census.		Deaths from Typhoid Fever During the Year											Total Number of Typhoid Deaths.	Average Typhoid Death Rate per 100 000.	Deaths in 1903.*
	1890.	1900.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901	1902.			
Madison	1 815	2 761	1	1	1	0	0	0	0	0	1	1	0	5	21	1
Skowhegan ...	5 068	5 180	2	1	1	2	0	0	0	1	0	0	0	7	12	1
Fairfield	3 510	3 878	0	2	1	0	0	2	0	1	0	1	1	8	19	
Oakland	2 044	1 913	2	0	1	0	0	2	1	0	0	2	0	8	37	
Newport	1 188	1 533	0	0	2	0	0	1	0	0	1	0	0	4	26	1
Pittsfield	2 503	2 891	0	0	1	3	2	0	2	3	1	1	1	14	18	1
Waterville ...	7 107	9 477	2	3	3	1	0	3	2	3	2	7	7	33	35	18
Augusta	10 527	11 683	9	7	6	5	5	5	19	8	1	9	4	81	66	31
Hallowell	3 181	2 714	0	1	2	1	2	1	1	0	0	4	2	14	45	1
Gardiner	5 491	5 501	0	2	0	0	1	2	2	2	1	2	1	13	22	1
Richmond ...	3 082	2 049	1	0	2	0	0	0	1	0	2	1	1	8	28	2

* NOTE. — These figures were compiled from the records of the city clerks, and are not official.

As a water supply for Augusta, the Kennebec, unfiltered, should have been condemned long ago, not only on account of the typhoid

epidemics directly traceable to the use of the water, but also on account of the evident pollution of the stream above Augusta. From Madison down, sewage and mill wastes pour into the river. At Waterville alone, only 17.1 miles above the intake at Augusta, the so-called "great sewer" of Waterville discharges continuously into the tail-race of the Lockwood Mills. (The sewerage system of Waterville has been gradually enlarged since its beginning in 1889, two years after the installation of the Augusta Water Company.) For three miles down stream, the fecal matter preserves its integrity, and for a longer distance toilet paper may be traced. Samples of the river-bed were dredged up at intervals, all of which, except those taken at the intake and a mile above, underwent a strong putrefaction in the course of seven weeks. When freshly taken, the sewage odor could be traced for seven miles below Waterville. Most of these samples were black slime, either scraped off a rocky bottom or brought up with sand or gravel.

At Augusta, as Mr. Whipple says, the possibilities of infection by media other than water were one by one excluded from consideration. In studying the distribution of the cases among the milk dealers it was found that one dealer, a Frenchman, had served thirty-three persons who were attacked with typhoid, while the highest number served by an American was ten. This apparent bunching of cases with one milkman was explained by the remarkable prevalence of typhoid among the French Canadians, his chief customers. In addition the cases were very evenly distributed over a period of two months. So far as I could ascertain, none of the milk dealers had a case of typhoid in their families or among their help, either before or during the epidemic.

In both Waterville and Augusta, there are large numbers of French Canadians, many of whom are employed in the mills. Some of them are so ignorant of sanitation that they do not distinguish between the functions of a urinal and a watercloset. An inspection of their homes and surroundings reveals as discouraging a situation. Many use privies which are as dangerous to the user as they are to the consumer of the water from the watershed. While this may be partly due to the negligence of the owners of the property, it is usually caused by the carelessness

of the tenants. Filthy back-yards and reeking pigsties and chicken coops drain directly into the stream. A striking example of the ease with which the Kennebec may be polluted was seen at Waterville. Several privies used by some thirty people were situated about thirty-five feet from low water, but well below high-water mark. The boxes were loosely joined, leaching on the ground. A French Canadian who was dawdling around noticed my interest in the privies and volunteered the remark that he had been greatly inconvenienced last spring because he had to clean out those privies. Usually he simply built a new set to replace the old which the spring freshet swept away bodily with the accumulation of filth for a year.

A study of the maps of both Waterville and Augusta, on which the typhoid cases were plotted, shows that a large percentage of the cases occurred among the poorer classes, particularly among these same French Canadians. For instance, in one family of eleven French Canadians, at Augusta, nine were sick with typhoid within two months. All had drunk river water. Probably some caught the disease from the earlier patients, for a survey of the premises a year later showed an unclean privy and an unkempt yard. Such general conditions as I have described do not detract from the virulence of the epidemic. They emphasize, however, a means to restrict the spread of epidemics which increase gradually, namely, by an efficient sanitary police who can not only instruct the people in cleanliness, but are empowered to force them to observe the elementary principles of sanitary science.

In conclusion, the writer would like to acknowledge the various courtesies afforded him by the officials of the Augusta Water District and the doctors of Augusta. Then, too, the uniform alacrity with which the people of Augusta furnished information materially lightened the labor of the extended investigation laid out by Mr. Whipple.

Mr. R. Winthrop Pratt* (by letter). By way of discussing the paper of Messrs. Whipple and Levy, I should like to submit a brief account of the severe typhoid epidemic which occurred at Columbus, Ohio, in the early part of 1904.

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* Engineer to the Ohio State Board of Health, Columbus, Ohio.

The population of Columbus at the time of the epidemic was about 150 000. Besides this resident population, there were present in the city a large number of visitors, due in part to the opening of the state legislature.

TABLE No. 21.

MONTHLY RECORD OF TYPHOID FEVER CASES AND DEATHS IN COLUMBUS, O.

Month.	Typhoid Cases Reported.	Deaths from Typhoid.			Death Rate per 100 000 per Year (based on resident deaths).	Death Rate per 100 000 per Year (based on total deaths).
		Residents.	Non-Residents.	Total.		
Dec., 1903	40			4		32
Jan., 1904	725	28	7	35	224	280
Feb., 1904	798	86	8	94	688	752
March, 1904	83	28	5	33	224	264
April, 1904	28	7	2	9	56	72

DAILY RECORD OF CASES.

	1904. Jan.	1904. Feb.	1904. March		1904. Jan.	1904. Feb.	1904. March
1	1	138	9	17	2	19	2
2	0	52	4	18	24	25	2
3	0	29	1	19	48	22	1
4	1	28	4	20	24	27	0
5	8	28	5	21	44	1	4
6	3	48	3	22	35	21	0
7	3	16	7	23	41	8	0
8	7	74	2	24	16	15	0
9	4	34	1	25	43	19	2
10	1	26	3	26	25	14	4
11	5	19	5	27	48	5	0
12	9	15	2	28	35	2	2
13	26	36	1	29	47	4	2
14	34	12	2	30	81		2
15	43	36	2	31	23		1
16	47	13	4				

The typhoid death rate for years previous to this epidemic had never been as great as that of many other cities. Sources of pollution to the water supply were, however, known to exist.

The death rate among the transient population was probably greater than that among the resident population; and furthermore there were many persons who contracted typhoid in Colum-

bus at this time and died elsewhere, their deaths not being included in the above table. This shows that the visitors to a city like Columbus, having a water supply subject to pollution, are more likely to be affected than are the residents. This is, probably, because the latter are in the habit of taking certain precautions in using the water while the former come to the city and use it carelessly or unsuspectingly. When the epidemic is fully under way, however, and the fact is known all over the country, then the visitors, or at least those with ordinary intelligence, are probably quite as careful about using the water as the residents.

Columbus is supplied with water from the following sources: *First*, the Scioto River; *second*, Filter Gallery on the bank of the Scioto River; *third*, Alum Creek, and *fourth*, wells driven along the bank of Alum Creek.

At the "West Side Pumping Station" water is pumped from the first two sources and supplied to the central or business part of the city as well as to the western and northern portions. About 11 000 000 gallons per day are supplied by this pumping station, and the proportion drawn from the river directly depends upon the quantity available from the filter gallery. The latter is used when possible but is never able to furnish enough water for any considerable time, so that the raw river water is almost always being pumped into the mains in greater or less amount. Just previous to the epidemic 3 000 000 to 4 000 000 gallons per day, out of the 11 000 000 pumped at the West Side Station, was raw river water.

At the "East Side Pumping Station" water from Alum Creek or from driven wells near by, depending upon the quantity available from the latter, is supplied to the eastern portion of the city. The quantity from this source is perhaps 75 per cent. of that furnished by the West Side Station.

Almost without exception the typhoid fever cases occurred among the residents of the district supplied with Scioto River water or among the business men who, though residing outside of this district, were supplied with Scioto River water at their offices. This fact proved that the water supply was the cause of the trouble and also showed that the Scioto River rather than Alum Creek was infected.

The watershed of the Scioto River above Columbus covers an area of 1 070 square miles and consists principally of farm land, although several communities, constituting serious sources of pollution to the river water, are located upon it.

Within 65 miles of Columbus, 27 towns and 4 institutions exist upon the river or its tributaries, representing a population of about 43 000, while the sewers of six of the towns and three of the institutions, representing a population of about 30 000, discharge directly into the river or its tributaries.

Although there are many places which might have infected the river water with typhoid bacilli, investigation has shown that by far the most probable cause of the epidemic was the State Hospital for Insane, one of the institutions referred to above, located within the city limits of Columbus.

The sewerage system at this hospital is rather unusual. The domestic sewage from the institution, which is occupied by some 1 600 people, is collected in an 8-inch or a 10-inch sewer laid within a 36-inch storm water sewer. A short distance away from the institution buildings the domestic sewer leaves the storm sewer and connects with the city's sewerage system; but the storm sewer discharges into Dry Run, which is a small, intermittent stream entering the Scioto River about a mile above the water-works intake.

Shortly after the epidemic broke out an inspection showed that the connections between the sanitary sewer and laterals, coming from various parts of the institution, were made in at least two cases by simply discharging the laterals into the big storm sewer and constructing a bulkhead immediately below the point of discharge, through which bulkhead the open end of the main sanitary sewer projected. Under these conditions, with every storm, the water collected by the storm sewer carried the accumulated filth from behind these bulkheads into Dry Run and thence to the river. Moreover, one of the bulkheads was found to be broken, permitting some of the sewage to flow continuously into Dry Run. It was necessary to take twenty-two and a half tons of putrefying sludge out of the storm water sewer in order to clean it.

Twelve cases of typhoid fever had occurred at the institution

one year previous to the epidemic, since which time there were no reported cases until January 3, 1904. The case reported on this date was soon followed by seven more, two of which died.

Typhoid fever had occurred to a greater or less extent at Kenton, the Girls' Industrial Home, near Delaware, and at Arlington, all having sewers discharging into the river or its tributaries, and possibly at the Stone Quarries, a small settlement of unsanitary character three miles above the intake of the Columbus water works.

There is no doubt that the Insane Hospital discharged the greatest amount of sewage into the river with the exception of the cities of Kenton and Marion. Therefore, considering this as well as the proximity of the institution to the water-works intake (one and one-half miles following Dry Run and the river), the extremely low stage of the river at this time, and the fact that there was typhoid fever at the institution at least ten days previous to the beginning of the rapid increase in the cases in Columbus, it seems fair to conclude that the principal factor in causing the epidemic, if not the sole cause, was the State Hospital.

It is to the credit of the citizens of Columbus that, realizing through this epidemic the importance of pure water, they voted last fall a bond issue of $1 200 000 for improving and filtering the water supply. A filtration plant will soon be built.

THE MISSISSIPPI RIVER AS THE SOURCE OF WATER SUPPLY FOR THE INHABITANTS OF THE MISSISSIPPI VALLEY.*

BY ERASTUS G. SMITH, PH.D., PROFESSOR OF CHEMISTRY, BELOIT COLLEGE, BELOIT, WIS.

[*Read March 8, 1905.*]

Gentlemen of the New England Water Works Association, — I am very glad to be here this afternoon to say something on the subject of the Mississippi River as the source of water supply for the inhabitants of the Mississippi Valley, a matter of considerable interest to the country at large, and especially to us in the West. The subject is so large and elastic that it might be made to cover any length of time, but the limited period at my disposal naturally forbids an extended study of the whole drainage area of the Mississippi basin. This area includes the territory between the Alleghany and Rocky mountains, the upper boundary of the United States and the Gulf, a field of study which you may well judge is too broad to be covered adequately within the limits of this discussion.

Note on a map the Mississippi River in its general course, and the Missouri, the Ohio, and the Illinois rivers. Observe the location of the cities of Minneapolis and St. Paul; further down, the cities of Dubuque, Davenport, Moline, Rock Island, Quincy, Burlington, and St. Louis; and finally New Orleans near the mouth of the river.

We are accustomed to speak of the "eastern slope" of the United States, the "western slope," and the "Mississippi basin." You will note that this basin is naturally divided into several districts, representing the drainage areas of the principal tributary rivers. But to-day I propose merely to speak of the drainage basin of the Mississippi River proper, simply alluding in passing

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* This address was illustrated with about seventy lantern slides, to which constant reference was made.

to these other large streams as they modify and affect the general character of the Mississippi River below the points where they join it.

There are certain contributory influences determining the various types of water carried which are quite important for us to understand thoroughly in this study of the Mississippi River. First, the drainage basin, extending over so great an area as it does, naturally would be subject to marked meteorological changes; the storms and the widely varying atmospheric conditions of the sections seriously affect the river. It is astonishing how markedly the waters of the Mississippi River, even in its upper portion, and still more so in the lower reaches, are affected by the sudden changes due to storms during the summer season. At Burlington, Iowa, for example, last year, the quality of the water would materially change overnight, the water on one day containing comparatively little suspended matter, and the next day being fairly thick and muddy from the amount of clay and silt which had been washed into the river during the night, owing to a storm which had arisen. Of course a part of this remains suspended and a part rapidly settles to the bottom of the river. Local floods thus caused and the fluctuations due to violent storms, charging the waters with suspended matter and, especially if the storms are prolonged, changing the relative amounts of dissolved matters and the alkalinity of the waters, — upon a knowledge of which the successful operation of purification works depends, — present most serious problems for the engineer to overcome successfully. In the same manner meteorological conditions affect the basins of the tributary streams, and hence more or less directly affect the main river.

A second element affecting to the condition of the Mississippi River is the *seasonal fluctuation*. This is a very important factor and one which has been too often lost sight of by those called upon to study the Mississippi River and to determine the most efficient method of the purification of its water. The water of the Mississippi River in the winter differs entirely from its condition in the spring, and especially in the months of May and June, when the waters are heavily laden with silt. It is also entirely different from its condition in August and September.

Curiously enough the river water during the early fall is often in its worst condition to purify properly. I do not know the exact reason for this, but it is associated with the low condition of the water affecting the upper drainage areas, and, probably, especially with the peculiar condition of the organic materials the waters carry.

A third influence seriously affecting the Mississippi River is the wide territory which it covers, and notably the great variety of geological formations the river traverses. The various branches of the river also traverse different geological horizons, and the materials added to the river from these exposures of different layers and horizons of rock seriously affect and modify the quality of the river water, and determine the diversity of problems of the sanitary engineer investigating the best method of treatment of the water.

If you will consider for a moment the character of these rocks of the various geological periods cut by the river, you will understand how they affect the quality of the river water. You know that granite is not soluble in water, and therefore the waters which fall on the territory where granite rocks are exposed do not become impregnated with mineral salts, but, draining off into the lake at the north and the Mississippi River to the west, they yield water of excellent quality, soft and quite free from mineral salts. The Silurian exposures which contain horizons of sandstone and limestone, and the Devonian, another area of limestone, give solutions of calcium and magnesium salts; the carboniferous exposure contributes in its own way solutions of lime and other salts; and thus the quality of the water, as we pass down the river, is materially changed. The whole territory to the northwest through the Dakotas is essentially a cretaceous deposit, so that the waters from the Missouri River are quite hard in character, and especially affect the lower ranges of the Mississippi.

Another interesting fact, which does not, however, appear from the map, is that the territory contiguous to the upper Mississippi River as far south as the upper tiers of counties of Iowa and Illinois is covered with a calcareous gravel, deposits from the great Ice Age, and varying in thickness from a few feet to some hundreds of feet at particular points. The waters from the sur-

face filtering down through this calcareous gravel take up part of the lime and magnesium salts, and thus are much increased in hardness. These calcareous gravels affect both the river waters and surface wells through the West, though not affecting the waters equally in this section of the country.

A fourth factor influencing the quality of the water is the content of the influent streams along the river. We have not time to go into the question in much detail, nor it is germane to this discussion, but water-works systems located at different points along the river are often materially affected by the inflow from small streams. The particular case ot Burlington already cited was due, not to a storm distributed along any considerable territory adjacent to the main body of the river, but to a storm purely local in character, which had affected a small influent stream finding its way into the main river three or four miles above the water works. I have seen the works at Davenport, for instance, operating well one day, and the next day the waters were fairly turbid from a storm which had vented itself upon a small stream emptying into the Mississippi River a few miles above. Thus the character of the influent streams, both large and small, is a very important factor in the study of the waters of the Mississippi River. These matters may not particularly interest you gentlemen here, who have to study streams of comparatively moderate length, but they are very important elements in the varied problems presented to engineers investigating our western supplies, because, while here you have to deal with comparatively short rivers, there we have to deal with rivers hundreds of miles in length, extending over wide territory, the character of the material changing in a few miles or a few hundred miles, and those materials being transported down the stream to the purification works below.

With this brief glance at some of the more important influences at work, let us consider for a moment the general appearance of the Mississippi River. The river itself is a broad, commanding stream, through both its upper and lower reaches; having no very decided falls, the river is navigable a great part of the open season as far north as St. Paul. The banks for the most part are high and precipitous upon either side.

What results do these agencies and others — and there are many of them — work in this stream? The first result is a condition, not exactly peculiar to the Mississippi River, but common to many of our northern rivers in the West, namely, the presence of large amounts of extractive material which comes from the lumber lands and from the great swamps lying to the north. The logs and lumber floating or rafted down the river as already mentioned, also impart large amounts of the extractive matter. The first quality imparted is the high color, which runs frequently at ordinary stages of the river as high as 40 on the scale with which waters are usually graded. Another peculiarity of this extractive matter in the Mississippi River is its rather acid character. I take it that this extractive matter coming down from these pine and hemlock and tamarack swamps to the north is largely material closely allied to the tannic acids, soluble in the water, as when it is studied it exhibits the characteristics of material directly taken from the barks. The nature of this material held in solution would be an extremely interesting question to investigate in detail, but we can merely allude to it in passing. This dissolved extractive matter is a gummy-like or albuminous material of a colloidal nature, which, held in suspension or in solution in the water, exhibits peculiar properties, especially when it is brought into contact with other colloidal solutions. As I shall develop later in connection with the ordinary processes of mechanical filtration by which alone this water can be successfully treated and purified, the exact nature of the dissolved material demands more thorough study than has yet been given it, as upon the correct understanding of it the intelligent application of all purification processes depends.

It should be noted in this connection that this extractive matter is extremely difficult to remove. There is need to emphasize this, because if any of you become interested in problems of this kind, or have to do with them, you will find that the removal of this matter presents the most serious difficulties. Alum seems to remove it most easily of anything. The compounds of iron, which have been recommended in later years, apparently do not materially affect this extractive matter of the upper Mississippi, and simple sand filtration hardly lowers the color of the river water.

The second result of the agencies at work on the Mississippi River water is the silt, one of the most interesting features of water purification in the West. In the East the rivers are clear as compared with the Mississippi River or the Ohio or the Missouri. To give you some idea of the amount of silt which is carried down by the Mississippi River, we have a résumé in tabular form of some of the results obtained by Humphreys and Abbott for the United States Survey in 1861. The mineral matter is present in the river in three forms: it may be in solution, or in suspension, that is, held in an exceedingly finely divided condition, or it may be as a coarser sand or gravel rolled along the bottom of the river. The amount of material carried in solution down the Mississippi River annually is something over one hundred million tons, which would be equivalent to one foot of the entire drainage surface in twenty-five thousand years, — the whole drainage area between the Rocky Mountains and the Alleghany Mountains, — this area being about a million and a quarter square miles in extent. The amount contained in suspension, that is, the silt, amounts, according to their determination, to something over four hundred million tons annually. That would be equivalent to one foot of the entire drainage surface in six thousand years. The amount contained as sand and gravel, which is too heavy to be floated in the river, but is rolled along the bottom of the river, amounts to seven hundred and fifty million tons annually, equivalent to one foot of the drainage surface in three thousand years.

The total removal by these three agencies working together would be an amount equivalent to one foot over the entire drainage area in every two thousand years. This amount each year is equivalent to a column a mile square at its base and 268 feet high; or, to put it in a little more tangible form, would make a column about thirteen times the area of Boston Common and 268 feet in height. This gives us some idea of the tremendous amount of material carried down the river annually. Of course these materials in suspension and solution, and the larger particles rolled along the bottom, present a very serious problem to the engineer when called upon to devise a system of purification for this river water.

Something should be said further regarding the sanitary signi-

ficance of this silt, because it is a factor of the problem too often disregarded. The silt contained in the Mississippi River is at once the burden of the engineer and at the same time the great means of self-purification of the river water. May I use a homely illustration? You have all taken a stone or a small snowball and rolled it along through the snow, and you know how the particles of snow tend to ball together. In exactly the same way these particles of silt moving along tend to become agglutinated or to cling together, so that the particles gradually become larger; as a result the water becomes clearer, the substances in colloidal solution become partially co-precipitated, bacteria and the micro-organisms of the water also adhere, and by their specific gravity, which is 1.9, that is about twice that of water, the particles gradually sink to the bottom. That, in itself, is a great agency for the auto-purification of our western streams. We heard a great deal about silt purification in the Chicago Drainage Canal case, and what it contributed, if anything, to the self-purification of the Illinois River. We hear of it continually in the study of the removal of materials from the river. Mr. R. S. Weston, in the admirable line of experimentation which he carried on for the proposed new works for New Orleans, showed the remarkable removal of bacteria in the lower reaches of the river due to the processes of sedimentation, increased and made more certain through the silt contained by the river water.

Another result from the agencies at work contributing to the pollution of the river, is the material carried in solution. I will simply note the fact that the waters of the river vary in mineral content, being mostly the carbonate of lime and magnesian salts in solution, and increase in hardness as samples are taken down the stream. This is of special interest, however, from the industrial standpoint, as it affects the use of water for boilers and manufacturing purposes, and I will not take your time to discuss it further now.

The fourth and the last result which I want to speak of to-day, and which I shall endeavor to emphasize again, is the contribution man himself makes to the pollution of a river water which was originally pure and clear along its upper reaches. If you examine the water front at St. Paul, Minn., you can see the sewers opening

into the river along the whole water front; had we a view of the water front of the city of Minneapolis you would find the sewers from that city emptying into the Mississippi, and could we follow the whole length of the river we would find that the waste and refuse and sewage of the cities is thrown out into the river, transforming it in reality into a great open sewer. And it is not only the sewage from the closets and the drains of the cities and the general waste and wash of the houses which is thus disposed of, for could we go down the Mississippi River at about this time of the year, before the break-up of the ice, we would find in front of any city, and especially somewhat below the city, heaps of ashes, waste, filth, dirt, night-soil, and dead animals thrown out upon the ice, there to remain only until the break-up comes in the spring, when the whole winter's accumulation is dumped into the river to be swept a little further down the stream to waste and decay along the bed of the river! What shall be said in extenuation of the action of municipalities in pursuing such a course and willfully polluting the water of the river below, which, as we shall see, is absolutely necessary for the water supply for this great territory?

With this understanding of the natural conditions controlling the influent waters, and the four chief agencies at work seriously controlling its quality, I want to speak of the water as it is actually used as a water supply. The attentive student of the water problem becomes more and more convinced that from the contour of the country, the nature of the soils, the rock exposure, the hard waters from the subsoil, from the conditions surrounding the cities ranged along the banks of the Mississippi, the people by necessity are practically driven to the river as the best and sometimes the only source of a public water supply.

At present there are in general four ways in which the water is taken and used for a public supply.

1. The first of them is that in use in Minneapolis, Minn., which, so far as I could recall in the preparation of this paper, is the only city taking its supply directly from the river and pumping the water, without any attempt at treatment, directly to the people. But that might not be so bad if Minneapolis would be reasonable

and take the water wholly above the city, — the country above the city being open, with no considerable pollution. The water, it is true, has a very high color because of the extractive matter already spoken of, but the river is not subject to polluting agencies, notably from the sewers and the manufacturing waste and débris from any great population.

In 1896 I was invited by Mr. Cappelen, at that time city engineer, to make a report upon the water supply of the city of Minneapolis. On investigating the situation I found the water above the city highly colored, charged with extractive matter, and in the report I recommended filtration of the water by mechanical filtration as the most efficient method of purification. The subject has been more fully investigated by engineers since that time, and I believe the reports have practically been unanimous in advising the filtration of the supply. But those suggestions have not been heeded, and what has been the result? There are now four pumping stations for the city of Minneapolis, one located near the center of the water front, another at a point just above the St. Anthony's Falls, both of these being in a part of the city below the out-fall of the sewers and notably below the discharge from Bass's Creek, which receives the discharge from sewers, so that the sewage from the city finds its way down the river to these intakes. The other pumping stations are located above the city, one on one bank of the river and the other (Station 4) on the other bank, having been erected since I was there in 1896. December 30, 1903, it was necessary, owing to lack of pressure, to start the pumps at Pumping Station No. 2. Immediately a typhoid fever outbreak occurred in the city of Minneapolis, of which you have been advised, as you have read engineering literature; and where were the cases located? They were located almost wholly in the section of the city taking its water supply solely from the station No. 2 above St. Anthony's Falls, the rest of the city being practically free from the disease. That was the penalty, or rather one of the penalties, which the city of Minneapolis has paid for not properly filtering or purifying the water of the river in some way.

2. A second method of treatment is the very simple one of simple sedimentation of the water, pumping it to a reservoir,

allowing it to stand for a period to allow the heavier particles time to separate out, and then drawing off water from the surface as the supply for the people. But, after all, there is nothing new about the purification of water in this manner. Many of you have been in Rome and have seen those great aqueducts stalking across the Campagna, by which the old Roman engineers brought water practically on a level from the base of the Apennines. Sometimes there were two, and even three, of these aqueducts, one above the other as they were forced still farther back after the water, bringing it in on a yet higher level. But what interests us most to-day is the fact that the old Romans had an idea of the purification of water, and that there is nothing new after all in the process of sedimentation. There were sometimes breaks in the old Roman aqueduct, in order to introduce a set of sedimentation chambers, remains of which have been found. There was the in-flow of the water from the aqueduct into one chamber, thence down into a second, thence into a third, then up into a fourth chamber, and so on out into the aqueduct again. What was the result? It simply stayed the force of the stream, allowing a chance for sedimentation, so that the sand and gravel as it rolled along upon the bottom of the aqueducts could settle down in these several chambers. Whenever necessary the current could be turned off and these chambers cleaned out.

As an example of modern sedimentation works, perhaps the most satisfactory in this country, and in constant use as long as any, I would cite those at Omaha, Neb., which deal with the waters of the Missouri River. The Missouri River is much more heavily laden with silt than the Mississippi, the water being of a muddy appearance through the greater portion of the year — its Indian name signifies "The Big Muddy." It is plain that this silt must be removed from the water before it is used. At Omaha the water is pumped up from the river into the upper basin, whence it flows over a low dam into a lower one and then into the third. I have seen the basins cleaned after a few weeks' use during the floods in the springtime when the waters were heavily charged with silt, and as much as sixteen feet of silt in one of these upper basins, an amount about one foot in depth at the same time being deposited in the second basin.

The process of sedimentation is used very largely upon the Mississippi River at the present time. At the filtration works at Davenport, Ia., a most efficiently operated works on the Mississippi River, it was found necessary to introduce a system of pre-sedimentation, particularly to get rid of the great body of silt brought down by the river, thus relieving the filters of a great deal of work which they otherwise would have to do. The settling basin is of heavy concrete construction, of a capacity of 5 000 000 gallons, allowing the water a full twenty-four hours' sedimentation. The water is pumped by a low-pressure pump, through a main reaching to the upper end of the basin; it is then skimmed off through a weir at the opposite end into the fore-bay where it is mixed with alum and after sedimentation and coagulation is delivered to the pumps for filtration. The cleaning is done by a water main which is laid on the floor of the basin, near the long side walls; jets of water issuing under pressure drive against the walls, and as the water flows back along the floor of the basin, men with shovers push the silt and coarser sand into a central gutter, through which it runs off to the sewer, discharging into the river below the intake, this being a very cheap and economical method of cleaning the settling basin.

Further down is the largest sedimentation system on the river, namely, that at St. Louis. The water works of St. Louis to-day are located at the Chain of Rocks above the city. It should be said in passing that the water is now treated with iron and lime, facilitating the rate of sedimentation; but at present few definite data are available upon the process, which is simply one of sedimentation.

The following interesting table is taken from the report of Mr. Flad to the city of St. Louis in 1900, and gives some idea of the immense amount of silt removed from the settling basins:

DEPTH OF SILT IN INCHES IN EACH BASIN. — ST. LOUIS WATER WORKS.

1899	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.		No. 6.		Cost.
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	
May	23	18	24	19									$955.97
June	23				32	28	33	29	36	30			1 293.99
July	24	18	20	14	19	14	17	12			39	34	857.57
September									14	10	17	12	174.50
October	24	19	22	17	22	17	17	12					433.87
Total . .	71	55	66	50	73	59	67	53	50	40	56	46	$3 715.90

NOTE. — Columns "a" show total sediment deposited; columns "b" show the sediment removed by manual labor.

The total amount of sediment deposited in the basins during the year was 317 000 cubic yards, of which 248 000 cubic yards was removed by manual labor, at a cost of $3 715.90, or 1.49 cents per cubic yard.

3. The third method of purification, namely, that of slow sand filtration, requires but brief consideration in this connection. We of New England are very apt to think of the purification of water by slow sand filtration as the best method of purification, and it is undoubtedly the best system with a moderately colored water, and where the suspended materials are low. But from what has been said you can understand why it is not readily applicable to the Mississippi River. In the first place, slow sand filtration does not materially remove color due to dissolved materials. In the second place, by that method you cannot filter a water so heavily charged with silt as this water. This is one of the reasons why the filters at Rock Island failed in 1900, at the time of the terrible outbreak of typhoid fever in that city. It has, therefore, been necessary to recommend some modified system with previous treatment in some form, as was done by Mr. Hazen at St. Louis, and by Mr. Weston at New Orleans, to prepare the water for the filtration by the slow sand process.

Slow sand filters, I want to say, are nothing new. They have been abundantly successful in Europe, and in this country where the water to be filtered was adapted to them, but they have thus far been inoperative upon the Mississippi River, for reasons I have

endeavored to make clear, and hence it is unnecessary for me to dwell longer upon them.

4. The fourth and last method, which has found extended and successful application upon the Mississippi River, is that of mechanical filtration. It is unnecessary to enter in any detail into the subject of mechanical filtration with this audience, as you are all undoubtedly familiar in a general way with its principles. Mechanical filtration is applicable to almost any natural water provided that water carries in solution certain amounts of dissolved salts. It depends primarily upon the presence of dissolved alkali in the natural water which can react upon materials added during the process. With the waters of the Mississippi Valley the alkali most commonly present is lime or magnesia, and the substance most commonly added is alum, or, more properly, aluminium sulphate, which in contact with the alkali contained in the water unites with it and forms an insoluble compound, aluminium hydroxide, which in turn acts upon the silt and other materials contained in the water so that they can be removed. The following alternate chemical equations express something of what happens.

$$\mathrm{Al_2(SO_4)3 + 3\,H_2}\underset{\substack{(\mathrm{Mg})\\(2\,\mathrm{Na})}}{\mathrm{Ca}}\mathrm{(CO_3)_2 = 2\,Al(OH)_3 + 3\,}\underset{\substack{(\mathrm{Mg})\\(2\,\mathrm{Na})}}{\mathrm{Ca}}\mathrm{SO_4 + 6\,CO_2}$$

$$\mathrm{Al_2(SO_4)_3 + 3\,}\underset{\substack{(\mathrm{Mg})\\(2\,\mathrm{Na})}}{\mathrm{Ca}}\mathrm{CO_3 + 3\,H_2O(+XCO_2) =}$$

$$\mathrm{2\,Al(OH)_3 + 3\,CaSO_4 + 3\,}\underset{\substack{(\mathrm{Mg})\\(2\,\mathrm{Na})}}{\mathrm{CO_2}}\mathrm{(+XCO_2)}$$

By the chemical reaction of the alkali dissolved in the water and the added alum, aluminium hydroxide is formed, and this being insoluble in water serves to entangle and ball together in a mechanical fashion, or as we say, "coagulate," these particles of silt. A point for future investigation is that this aluminium hydroxide separates out in what is known as the colloidal condition, which appears to exert a remarkable influence upon micro-organisms and the bacteria contained in the water, fixing and removing them with the silt and other suspended matters. This is particularly true of certain other metals, and will be the subject

of interesting future study by those who have to do with the purification of our water supplies.

The amount of alum which must be added to give maximum efficiency of purification is a matter purely of experiment, at particular points where plants are to be installed. It is necessary only to refer to the brilliant experimental work done in these later years by Mr. E. B. Weston at Providence, Mr. George W. Fuller at Louisville, Mr. Allen Hazen at Pittsburg, and by Mr. Robert S. Weston at New Orleans upon the problem of the amount of material which shall be added in order to purify the river water, to indicate the extent to which such investigations must be carried.

The problem of properly purifying the water of the Mississippi River, of such high color and heavy burden of silt, contaminated also with industrial waste and municipal sewage, is a most complicated one. Where demand for purification of the water has arisen, it has been met most satisfactorily thus far, by the installation of plants of the mechanical type. At present there are at least ten important points on the river where the waters are thus filtered and purified. The plants differ somewhat in construction and efficiency, but in the main the general type of construction is the same. At some plants the filters are of the gravity type; at others, of the pressure type; while at Moline, the most recent plant installed upon the river, the construction is of solid concrete masonry throughout.

The filter plant at Davenport Ia., is the one with which I am most familiar. The plant is of the type known as pressure filters, and consists of ten cylinders, resembling large boilers, each cylinder divided into three compartments. In each compartment there is placed about sixty inches of sand, the sand used being that from near Red Wing, Minn. As you will note, the sand is washed by a current of water issuing from the set of arms, which can be raised and lowered through the sand bed by hydraulic pressure. During the process of washing, the materials which have accumulated upon the surface of the sand bed, or have penetrated more deeply into the bed itself, are carried away by the constant stream of water through the sewer pipes, discharging into the river below the intake.

Alum is used as a coagulant, it having been found to be the most satisfactory material to use with the rather high color content of the river water at this point.

It is interesting to note the difference in bacterial content between the water taken from the channel of the river and water taken more near shore, as is found by comparing results of the plant at Davenport and the plant at Moline, which takes its water nearer shore, a short distance above.

As compared with the best results obtained elsewhere, with mechanical filters, as at Lorain, Ohio, and Little Falls, N. J., they compare most favorably. Also the results will be found to compare most favorably with those obtained by the process of slow sand filtration, as at Ashland, Wis.; Lawrence, Mass.; Albany, N. Y.; London, England; and Altona, Germany.

The use of materials other than alum has been advocated in connection with the Mississippi River water, in particular the use of iron sulphate and lime. At Quincy, Ill., the introduction of the so-called iron-lime process has been found to be fairly satisfactory, but at Moline, Ill., during a test run covering a period of sixty days, during May and June, 1904, it was found that the process was less satisfactory than alum, especially in removal of the color of the water due to dissolved materials.

The subject of the Mississippi River as the source of water supply for the inhabitants of the Mississippi Valley was chosen for this occasion because of the tremendous significance of the water supply of the Mississippi Valley of the present and the future affecting so vitally such an immense population. If you will study the last census reports you will be astonished to find how vast a population to-day takes its water supply — being fairly forced to take it by the very nature of the adjoining country — from this great open sewer, polluted by the refuse from the cities above. A little computation will show you that above the city of St. Louis there is the waste from a population of fully a million and a half of population, that from the Missouri there is the waste of half a million population, from the Illinois River the waste from a population of two millions, from the Ohio River of a population of a million and a half, and below St. Louis a half a million, making a total of upwards of six millions at the present time whose waste

is draining into what must be the water supply for the whole lower valley.

And what of the future of this population? A very ingenious scheme is one found in the St. Louis water reports in which they have plotted out the results contained in census reports for fifty years. From the plotting you see how the city of New York is growing, how in the city of Philadelphia and the city of Chicago the population curve is rising rapidly; that of the city of St. Louis rising almost as rapidly, the city of Cincinnati on a steady increase, the city of New Orleans on a steady increase. Gentlemen, what will fifty years more show in the cases of the cities of the Mississippi Valley, providing the rate of increase continues during the next fifty years as it has through the last fifty? Who can foretell how vast is the population bound to come into the Mississippi River valley, and which, if present conditions continue, will discharge its waste into the river, each city thus becoming a polluting agency to the water below?

There are at present upon the Mississippi River proper 25 public water supplies, of which number 16 are under private administration and 9 under public administration. Where water is supplied under private administration 11 supplies are filtered and 5 are unfiltered. The population supplied with filtered water under private administration is 192 000 and with unfiltered water 43 000, or a total of 235 000. Of the supplies under public administration there are only two which furnish filtered water; one of those, at Rock Island, is of questionable efficiency, and the other, at Moline, has just been installed. The population supplied with filtered water under public administration is 33 000; the population supplied with unfiltered water is 1 117 000.

In closing, I must only add that the one particular subject I wished to interest you in to-day is that of the preservation of the purity of our great natural water courses. The Mississippi River is the most striking example this country affords of the abuses to which a natural water course is subjected. Whatever force there may be to the argument for the self-purification of running streams, in the efficiency of systems of purification by sedimentation and filtration installed for the protection of the public, the fact remains that waters which from the very conditions of environment

must be taken as the normal food supply of the people should not at the same time be made the carriers of sewage and waste of a great and rapidly growing population. All principles of sanitary science are against such a course, and the esthetic nature revolts at the idea. The fullest protection to the public possible against such procedure is the problem which I want to interest you in, and in closing I wish once more to raise a protest against the present needless, not to call it criminal, proceeding of our inland American cities, whereby the waste is thrown out into the rivers to be washed down the stream, without any interposition by the state or national government to protect the lives and health of its citizens. This, gentlemen, is a problem to which water-works engineers and water-works managers, not to speak of the public at large, ought to give their time and study and their best ability.

The President. We should be glad to hear further on this subject from Mr. Fuller.

Mr. George W. Fuller. I wish to express my appreciation of the admirable way in which Professor Smith has set forth the general features of the problem in the Mississippi Valley. I think he has put before you its salient features, and I wish to subscribe to his closing sentiment. His statement of the case has been very clear, and I will not attempt at this late hour to go into any further details. I will merely say again that I think his view is thoroughly sound and correct, and I am happy to endorse it.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, Mass., March 8, 1905.

President George Bowers in the chair.

The following members and guests were present:

Members.

S. A. Agnew, F. E. Appleton, Edward Atkinson, C. H. Baldwin, L. M. Bancroft, F. D. Berry, J. F. Bigelow, J. M. Birmingham, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, James Burnie, J. C. Chase, H. W. Clark, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, B. I. Cook, J. W. Crawford, E. D. Eldredge, August Fels, C. R. Felton, F. L. Fuller, G. W. Fuller, J. C. Gilbert, A. S. Glover, F. W. Gow, R. A. Hale, J. O. Hall, J. C. Hammond, Jr., J. D. Hardy, T. G. Hazard, Jr., D. A. Heffernan, B. E. Helme, H. G. Holden, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, L. P. Kinnicutt, J. W. Locke, E. E. Lochridge, S. H. McKenzie, Hugh McLean, H. V. Macksey, A. E. Martin, W. E. Maybury, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. L. Northrop, Dwight Porter, J. B. Putnam, W. H. Richards, W. W. Robertson, A. T. Safford, E. G. Smith, J. T. Stevens, T. V. Sullivan, W. F. Sullivan, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, R. S. Weston, G. E. Wilde, F. B. Wilkins, C.-E. A. Winslow, G. E. Winslow, F. E. Winsor, E. T. Wiswall, E. Worthington, Jr. — 76.

Honorary Members.

Wm. T. Sedgwick, F. W. Shepperd. — 2.

Associates.

Ashton Valve Co., by Harry H. Ashton; Harold L. Bond & Co., by Harold L. Bond; J. B. Campbell Brass Works, by W. R. Darrow; Coffin Valve Co., Co., by H. L. Weston; H. A. Desper; Wm. H. Gallison Co., by N. E. Stilphen; Wm. H. Greenwood; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, H. D. Winton, W. A. Hersey; Kennedy Valve Co., by M. J. Brosnan; H. Mueller Mfg. Co., by W. L. Dickel; National Meter Co., by Chas. H. Baldwin, J. G. Lufkin; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by F. S. Bates; A. P. Smith Mfg. Co., by F. N. Whitcomb; Sumner &

Goodwin Co., by H. A. Gorham; Union Water Meter Co., by Edward P. King, W. F. Hogan, F. L. Northrop; the Platt Iron Works Co., by F. H. Hayes. — 23.

GUESTS.

Frank L. Weaver and M. J. Dowd, water commissioners, Lowell, Mass.; Thomas Moynihan and Patrick J. B. Sullivan and M. J. Doyle, Holyoke, Mass.; C. B. Cummings, H. A. Monk, Braintree, Mass.; F. W. Dinwiddie, water registrar, Gardner, Mass.; Wm. French, Worcester, Mass.; M. O. Leighton, chief division of hydro-economics U. S. Geological Survey, Washington, D. C.; Theodore Moorehead, Chinese government service, Shanghai, China; Edw. H. Keith, mayor, Brockton, Mass. — 12.

[Names counted twice — 3.]

The following were elected to membership:

Resident. — Michael J. Doyle, Holyoke, Mass., water commissioner; W. B. Claflin, Jr., Hopkinton, Mass., water commissioner and superintendent of the Hopkinton Works; Irving S. Wood, Providence, R. I., assistant engineer in charge of water department of the city engineer's office, Providence, R. I.

Non-Resident. — H. E. Jordan, Indianapolis, Ind., bacteriologist and chemist to the Indianapolis Water Company; Marshall O. Leighton, U. S. Geological Survey, Washington, D. C.

The Secretary read the proposed change of by-laws, as follows:

That Sect. 1, Article III, be amended by the addition of the following clause: "All applications for membership presented to the Association for action must be accompanied by the proper initiation fee and dues for whole or fractional part of current year in which application is presented."

That Sect. 5, Article III, be amended to read: "The annual membership dues shall be payable in advance on the date of the Annual Meeting in January. At the expiration of ten months after the Annual Meeting, the Secretary shall notify each member who has not paid his dues for the current year, that unless the same are paid within thirty days, his membership in the Association shall cease; and if said dues are not paid within said period, the Secretary shall drop the name of said member from the membership roll. The Executive Committee may, however, at its discretion, reinstate said person on the payment of all arrears."

That Sect. 4, Article VI, be amended by the addition of the following clause: "He shall deposit all funds received in such place of deposit as may be approved by the Executive Committee. All orders for withdrawal of funds and checks for disbursements shall be signed by the Treasurer and countersigned by the President."

Mr. Dexter Brackett. Before a vote is taken, I should like to have some one explain the reason for the amendment to Section 1, Article III.

Mr. R. C. P. Coggeshall. In relation to that I will say that the auditing committee, Mr. Robertson and myself, when we examined the books and accounts, were impressed with the fact that quite a number of members have been elected for two years and have never paid their initiation fee or their dues. Under the by-laws of the Association that was possible, for if they did not pay, they could not be dropped until the end of two years.* Now it seemed to us that if any one thought it was worth while to become a member of this Association, it was no more than right that he should do what is required by other associations of a similar character, and that is when he presents his application for membership present his initiation fee with it.

Mr. Brackett. I am very sorry to disagree with my friend Mr. Coggeshall, but it does not seem to me that it is necessary to require an applicant for admission to the Association to send with his application the money with which to pay his initiation fee. I am sorry to hear that any one who has been elected a member has not thought it advisable after that to pay his initiation fee, and at least one year's assessment; but I had supposed that a man was not a member until he had paid his initiation, and I should certainly be in favor, if the constitution does not so provide, of an amendment to it to that effect. The next amendment, that to Section 5, provides that a person can be dropped at the end of the year, so he wouldn't be a member any longer than that anyway; and it doesn't seem to me it is desirable to have a clause in the constitution in the form proposed. I do not think it looks well. I may be wrong about it, but that is the way I feel.

The President. Will you suggest any amendment?

Mr. John C. Chase. With all deference to Mr. Coggeshall, I think his view in relation to presenting the initiation fee with the application does not apply to societies of this sort, although it does apply to a very large number of other societies. I think that, as Mr. Brackett has suggested, if the constitution could be

* A person elected did not, however, become a member until he paid the fees and signed the constitution.—Editor.

amended so as to specify that membership should not be effective until after the initiation fee is paid, that would cure the difficulty which now seems to exist.

Mr. Brackett. As I do not suppose this is a matter which needs to be rushed through, I would move that the matter be laid upon the table until the next meeting and possibly it can be arranged in the meantime in some different form.

Mr. W. W. Robertson. I should prefer that the matter be acted upon now, and either an amendment made to the amendment as proposed, or else a vote taken upon the amendment as it stands, because the next meeting is some way off, pretty well toward the beginning of another year. As members of the Auditing Committee, we took it upon ourselves to look over the membership roll, and we found such a condition existing that we thought something should be done; and although this may appear a little radical, yet at the same time I think the action is perfectly justified. If there is any way of accomplishing the desired result in a milder way I should be satisfied as one of the committee, but I think the matter should be acted upon now instead of later.

Mr. J. C. Hammond, Jr. I am in favor of the amendment as proposed by the Committee. It is no cheap thing to become a member of this Association, and I think it is well to put on the bill, "Cash on Delivery."

Mr. Brackett's motion to postpone the consideration of the amendment to Section 1, Article III, was lost.

The amendments as read were then severally adopted.

The first paper of the afternoon was by Mr. William F. Sullivan, assistant engineer, Lowell, Mass., his subject being: "Test of Large Meters and Fire Supply Devices." Mr. Edward Atkinson discussed the matter from the fire underwriters' standpoint, and further discussion was postponed until the next meeting.

Prof. Erastus G. Smith of Beloit College, Beloit, Wis., gave an address on "The Mississippi River as the Source of Water Supply for the Inhabitants of the Mississippi Valley." His remarks were illustrated by a large number of stereopticon views.

Professor Sedgwick of the Institute of Technology was on the program to speak on "The Chicago–St. Louis Drainage Canal

Case," and Mr. C.-E. A. Winslow, instructor in sanitary bacteriology at the Institute of Technology, it had been announced, would describe "A Visit to Some Interesting Municipal Water Filters now under Construction." Owing to the lateness of the hour, they asked, through the President, to be excused, and they will present their papers at the first meeting in November.

The report of the Meter Rates Committee being in order, Mr. Freeman C. Coffin, chairman of the committee, said: "It is so late now that while the committee have their report ready, it seems to me it might be wise to read it by its title, and then advance copies can be printed and sent to the members of the Association, so that they will be prepared to discuss it at the next meeting."

On motion it was so voted.

Adjourned.

MEETINGS OF THE EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association March 8, 1905, at headquarters, Tremont Temple, at 11.30 A.M.

Present: President George Bowers, and Messrs. Lewis M. Bancroft, Frank E. Merrill, Robert J. Thomas, Frederick W. Gow, Edmund W. Kent, James L. Tighe, and Willard Kent.

The following-named applications for membership were received, and it was voted to recommend the same to the Association for election to membership:

As Members. — W. B. Claflin, Jr., water commissioner and superintendent water works, Hopkinton, Mass.; Irving S. Wood, assistant engineer in charge of water department of city engineer's office, Providence, R. I.; Michael J. Doyle, water commissioner, Holyoke, Mass.; H. E. Jordan, chemist and bacteriologist, water company, Indianapolis, Ind.; Marshall O. Leighton, chief division of hydro-economics, U. S. Geological Survey, Washington, D. C.

Mr. Kent, for the Committee on Treasurer's Bond, reported that the Treasurer has presented a guarantee bond of the Fidelity Trust and Deposit Company of Maryland for five thousand dollars, whereupon it was voted: That said bond be accepted and filed with the Secretary.

Voted: That the People's Institution for Savings of Worcester, Mass., the Mechanics' Savings Bank of Reading, Mass., and the First National Bank of Reading, Mass., be approved as places of deposit for the funds of the New England Water Works Association.

Voted: That George H. Snell, Frank E. Merrill, and Willard Kent be a committee to make arrangements for the June meeting of the Association.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association May 17, 1905, at headquarters, Tremont Temple, Boston.

Present: President George Bowers, Frank A. Andrews, Frederick W. Gow, Edmund W. Kent, James L. Tighe, Robert J. Thomas, Willard Kent, Lewis M. Bancroft, Charles W. Sherman, George A. Stacy, Frank E. Merrill, and George H. Snell.

Six applications for membership were received and approved, *viz.*, James M. Caird, 271 River Street, Troy, N. Y.; Wallace Greenalch, superintendent Bureau of Water, Albany, N. Y.; Theodore A. Leisen, chief engineer Water Department, Wilmington, Del.; William W. Locke, sanitary inspector, Metropolitan Water and Sewerage Board, South Framingham, Mass.; Charles H. Campbell, superintendent Water Works, Charlotte, N. C.; Luis Matamoros, municipal engineer, San Jose, Costa Rica, Central America.

Mr. George H. Snell, water commissioner of Attleboro, extended an invitation to the Association to visit Attleboro for the June outing, to inspect the reinforced concrete standpipe now in process of construction.

On motion of Mr. Stacy, it was voted: That Mr. Snell's invitation be accepted.

The subject of headquarters was introduced and after discussion it was voted: That the President, Editor, and Secretary be a committee to consider the subject of lease of rooms and to report to the Executive Committee.

The subject of annual convention was then considered. A letter from Mr. Hazen, secretary of the committee to make arrangements for same, was received and read, and Mr. Thomas, of the committee, made an interesting report of the progress of arrangements.

Mr. Merrill, Committee on Transportation, reported arrangement of fare and one-third rates for excursion to New York via Hoosac Tunnel and Hudson River, or via Fall River.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

BOOK NOTICE.

"Cement and Concrete." By Louis Carlton Sabin, B.S., C.E., Assistant Engineer, Engineer Dept., U. S. Army, M. Am. Soc. C. E. Cloth, 6 x 9¼ in., pp. 507 (incl. 11 pp. of Index), 161 tables. McGraw Publishing Company, New York. Price, $5.00.

In his preface, the author says, "The original investigations forming the basis of the work were made in connection with the construction of the Poe Lock at St. Mary's Falls Canal, Michigan." "When not otherwise stated, the tables in the work are condensed from the results of the above-mentioned investigations. In supplementing the original matter much use has been made of the experiments of others."

Part I contains two brief chapters defining the various kinds of cement and briefly describing the methods of manufacture. Part II, "Properties of Cement and Methods of Testing," contains 122 pages. Only 5 pages are devoted to "Composition and Analysis," and no methods of making analysis are given. The physical tests are discussed in considerable detail, but the details of manipulation of the tests are not given. Part III, "The Preparation and Properties of Mortar and Concrete," contains 186 pages, and is certainly one of the best available treatises on this subject. Some data of actual cost of concrete of various proportions are given, and the effects of age, of regaging, of frost, and of the admixture of various substances are discussed in considerable detail. 142 pages are devoted to Part IV, "Uses of Mortar and Concrete," including a brief chapter on reinforced concrete. Considering its importance, the subject of Forms receives very brief treatment. Most or all of the uses of concrete are described in more or less detail and generally with figures of cost of work actually constructed.

As a whole, this book is very satisfactory, and it will unquestionably take place as a standard treatise on the subject.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XIX. September, 1905. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

WATER-WORKS STATISTICS FOR THE YEAR 1904, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY CHARLES W. SHERMAN, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The following tables contain more or less complete statistics for forty-seven water works, which have used, more or less closely, the form adopted by the Association for summarizing statistics. Some of these works report under very few of the headings of the summary.

The editor has made no attempt to compile statistics from water-works reports which do not include at least a partial summary. Some other places have, no doubt, published summaries, but their reports have not been available.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of Vol. XV of the JOURNAL (March, 1902). The page for Financial Statistics was changed by vote of the Association in September, 1902, as reported in the December, 1902, JOURNAL (Vol. XVI, p. 263). Blank forms for use in preparing summaries are printed by the Association, and will be furnished on request.

Previous compilations of statistics may be found in the JOURNAL, as follows:

Statistics for	*Reference to Journal.*
1886	Vol. I, No. 4, p. 29
1887	Vol. II, No. 4, p. 28
1888 to 1892 inclusive	Vol. VII, p. 225

Statistics for	*Reference to Journal.*
1893	Vol. IX, p. 127
1894	Vol. X, p. 131
1895–96	Vol. XII, p. 273
1897–99	Vol. XV, p. 65
1900	Vol. XV, p. 367
1901	Vol. XVI, p. 223
1902	Vol. XVII, p. 235
1903	Vol. XVIII, p. 277

In the various tabulations, statistics are given for the following places and years:

Place.	*Year.*
Albany, N. Y.	1900
Andover, Mass.	1900
Arlington, Mass.	1900, 1904
Atlantic City, N. J.	1898, 1900–04
Attleboro, Mass.	1894–1904
Bay City, Mich.	1886–87, 1893–96, 1900–04
Belmont, Mass.	1902–04
Beverly, Mass.	1903
Billerica, Mass.	1899–1904
Boston, Mass.	1886–94, 1897, 1900, 1903
Bridgeport, Conn.	1904
Brockton, Mass.	1893–1904
Burlington, Vt.	1886–1904
Cambridge, Mass.	1900–04
Chelsea, Mass.	1900–04
Cleveland, Ohio	1902–04
Concord, N. H.	1895, 1898, 1900–04
Dover, N. H.	1900
Erie, Pa.	1900
Essex Junction, Vt.	1900
Fall River, Mass.	1886–95, 1897–1904
Fitchburg, Mass.	1886–92, 1894–1904
Freeport, Me.	1901
Geneva, N. Y.	1900
Haverhill, Mass.	1900, 1904
Holyoke, Mass.	1886–92, 1897–98, 1900–04
Hull, England	1900
Ipswich, Mass.	1900
Keene, N. H.	1899–1900, 1903–04
Lawrence, Mass.	1902–04
Leicester, Mass.	1900
Leominster, Mass.	1900
Lewiston, Me.	1900

Place.	*Year.*
Lowell, Mass.	1886, 1897–1904
Lynn, Mass.	1888–98, 1900–04
Madison, Wis.	1900, 1902–04
Manchester, N. H.	1900
Marlborough, Mass.	1900, 1903–04
Maynard, Mass.	1901–03
Metropolitan Water Works, Mass.	1900–04
Middleboro, Mass.	1895–1904
Middletown, Conn.	1902
Minneapolis, Minn.	1900–04
Nantucket, Mass.	1900
Nashua, N. H.	1900, 1904
New Bedford, Mass.	1886–1904
New London, Conn.	1886–1904
Newton, Mass.	1888–1904
Norwich, Conn.	1901
Oberlin, Ohio	1893–1904
Plymouth, Mass.	1886–1904
Providence, R. I.	1897–1904
Quincy, Mass.	1893, 1900–01
Reading, Mass.	1893, 1895–1904
Reading, Pa.	1901–04
Rochester, N. Y.	1903
St. John, N. B.	1902–03
Salem, Mass.	1900
Sandusky, Ohio	1886
Schenectady, N. Y.	1886, 1900–01
Somerville, Mass.	1900–04
Springfield, Mass.	1886–1904
Taunton, Mass.	1886–1904
Toronto, Canada	1893
Trenton, N. J.	1886–87
Troy, N. Y.	1886, 1888–93, 1897–99
Waltham, Mass.	1886–1904
Ware, Mass.	1886, 1888–92, 1900–04
Watertown, Mass.	1900
Wellesley, Mass.	1888–93, 1898–1904
Westerly, R. I.	1902–04
Whitman, Mass.	1897–1904
Wilmington, Del.	1900
Winchendon, Mass.	1900–04
Woburn, Mass.	1900–04
Woonsocket, R. I.	1886–1900, 1902–04
Worcester, Mass.	1900
Yonkers, N. Y.	1893–96, 1900–04

1904.—TABLE 1.—GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1 Builders of pumping machinery.	2.—Description of fuel used. a Kind.	b Brand of coal.	c Av. price per gross ton.	d Per cent. of ash.	e Wood. Price per cord.
1	Arlington, Mass.	1872 1894	Town.	Metropolitan W.W.	....	....	....	....	.....	..	...
2	Atlantic City, N. J.	1882 1888	City.	Wells and Absecon Creek.	Pumping.	Worthington, Gordon-Max'll, d'Auria, Rand, Smith-Vaile.	Bituminous.	Standard, Eureka, Priscilla.	$4 00	10	...
3	Attleboro, Mass.	1873	Town.	Well.	Pumping.	Deane, Barr.	Bituminous.	New River.	.....	..	...
4	Bay City, Mich.	1872	City.	Saginaw Bay.	Pumping.	Holly.	Bituminous.	Slack.	1 98	23	$2 50
5	Belmont, Mass.	1887	Town.	Metropolitan W.W.	....	....	....	....	.....	..	...
6	Billerica, Mass.	1898	Town.	Driven Wells.	Pumping.	Barr.	Bituminous.	New River, Victor.	1 86	..	...
7	Bridgeport, Conn.	1858	Co.	Streams.	Gravity and Pumping.	Worthington.	Bituminous.	....	1 00	..	...
8	Brockton, Mass.	1880	City.	Storage Reserv'r on Salisbury Brook; Silver Lake.	Pumping.	....	....	....	.....	..	...
9	Burlington, Vt.	1867–8	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	Nonpareil, Clearfield.	4 10 3 165	..	...
10	Cambridge, Mass.	1855	City.	Hobbs Brook, Stony Brook, Fresh Pond.	Pumping.	Leavitt (Gro'n) Worthington, Blake.	Bituminous.	Cumberland, New River.	4 20	..	...
11	Chelsea, Mass.	1867	City.	Metropolitan W.W.	....	....	....	....	.....	..	...
12	Cleveland, Ohio.	1856	City.	Lake Erie.	Pumping.	Worthington, Knowles, Allis, Kilby, Holly.	Bituminous.	Salineville Slack, Pittsb'g Sl'ck.	1 79	..	...
13	Concord, N. H.	1872	City.	Penacook Lake.	Gravity and Pumping.	....	....	....	.....	..	...

14	Fall River, Mass.	1874	City.	N. Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	Cumberland, Georges Cr.	.....	..	...
15	Fitchburg, Mass.	1873	City.	Storage Reservoir.	Gravity.	....	....	....	.....	..	...
16	Haverhill, Mass.	..	City.	Ponds.	Gravity and Pumping.	Worthington, Deane, Barr.	Bituminous.	Cumberland, Carbon.	$5 20	9.5	...
17	Holyoke, Mass.	1873	City.	Lakes, Streams, and Manhan River.	Gravity.	....	....	....	.....	..	...
18	Keene, N. H.	1868	City.	Sylv'n & Echo L'k's.	Gravity.	....	....	....	.....	..	...
19	Lawrence, Mass.	1874–5	City.	Merrimac River.	Pumping.	Barr, Morris.	Bituminous.	Georges Cr., New River.	5 53	8.18	...
20	Lowell, Mass.	1870–3	City.	Driven Wells.	Pumping.	Morris, Worthington, Deane, Knowles.	Bituminous.	Somnan, New River.	4 75	..	...
21	Lynn, Mass.	1871	City.	Ponds and River.	Pumping.	Leavitt, Loretz.	Bituminous.	Georges Cr.	4 75	11	..
22	Madison, Wis.	1882–3	City.	Artesian Wells.	Pumping.	Allis, Knowles.	Anthracite.	Pea.	6 98	..	...
23	Marlboro, Mass.	1883	City.	Lake Williams, Millham Reserv'r.	Pumping.	Blake, Worthington, Barr.	Bituminous.	Various.	5 09	..	...
24	Metropolitan Water Works, Mass.	1848, 1872, 1895	State of Massachusetts.	L. Cochituate, Sudbury River, Nashua River.	Pumping, 74%. Gravity, 26%.	*Chestnut*	*Hill High*	*Service Stat'n.*			
						Holly, Quint'd, Allis.	Bituminous.	Quemahoning George's Cr., Pocahontas, Cumberl'nd.	3 87	12	...
							Anthracite.	Buckwheat, Screenings.			
						Chestnut Hill	*Low Service*	*Station.*			
						Holly.	Bituminous.	Quemahoning Georges Cr., Pocahontas, Cumberl'nd.	3 97	12	...
							Anthracite.	Buckwheat, Screenings.			
						Spot	*Pond*	*Station.*			
						Blake, Holly.	Bituminous.	Georges Cr., Cumberland.	3 65	14	...
							Anthracite.	Buckwheat, Screenings.			

1904. — TABLE 1, *Continued*. — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1. Builders of pumping machinery.	2. — Description of fuel used. a. Kind.	b. Brand of coal.	c. Av. price per gross ton.	d. Per cent. of ash.	e. Wood. Price per cord.
25	Middleboro, Mass.	1885	Fire Dist.	Well.	Pumping.	Deane.	Bituminous.	Pocahontas, Georges Cr., Pardee.	$1 55 5 80	. .	. . .
26	Minneapolis, Minn.	1868	City.	Mississippi River.	Pumping.	Strothman,[1] Worthington, Holly.	Sawdust, edgings, etc. (Sta. No. 3), Coal (Sta. No. 1).	. . . .	. . . . .	. .	. . .
27	Nashua, N. H.	1853	Co.	Pennichuck Br. and Springs.	Pumping.	Snow, Deane.	. . . .	. . . .	. . . . .	. .	. . .
28	New Bedford, Mass.	1866	City.	Quittacas Ponds.	Pumping.	McAlpine, Worthington, Dickson.	Bituminous.	Georges Cr. Cumberland.	5 67	7	. . .
29	New London, Conn.	1872	City.	Lake Konomoc & Barns Reservoir.	Gravity and Pumping.	. . . .	. . . .	. . . .	. . . . .	. .	. . .
30	Newton, Mass.	1876	City.	Coll. Gallery near Charles River.	Pumping.	Worthington.	Bituminous. Anthracite.	Pocahontas, New River, Screenings.	3 77	10	$6 00
31	Oberlin, Ohio.	1887	Village.	East Branch of Vermilion River.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 00	. .	. . .
32	Plymouth, Mass.	1855	Town.	Gt & Little South and Lout Ponds.	Gravity and Pumping.	Barr, Worthington.	Bituminous.	Various.	1 90 5 50	. .	. . .
33	Providence, R. I.	1870	City.	Pawtuxet River.	Pumping.	Worthington, Paulding-Kemble, Corliss, Providence, Holly.	Bituminous.	Georges Cr., Pocahontas, New River.	4 72	11	1 50
							Bituminous.	Georges Cr., New River.	4 57	14	4 50
							Anthracite.	Buckwheat.	2 75	21	4 09
							Bituminous.	New River.	4 26	9	4 50

34	Reading, Mass.	1890	Town.	Filter Gallery.	Pumping.	Blake.	Bituminous.	Pocahontas.	$5 35	. .	. . .
35	Reading, Pa.	1819	City.	Creeks and Springs.	Gravity and Pumping.	Worthington, Allis-Chalmers.	Bituminous, Anthracite.	. . . .	2 96	9	$3 50
36	Somerville, Mass.	1868	City.	Metropolitan W.W.	. . . .	. . . .	. . . .	. . . .	. . . . .	. .	. . .
37	Springfield, Mass.	1864	City.	Reservoirs.	Gravity.	. . . .	. . . .	. . . .	. . . . .	. .	. . .
38	Taunton, Mass.	1876	City.	Lakeville Ponds.	Pumping.	Holly, Allis.	Bituminous.	Georges Cr., Cumberland.	5 25, 4 75 & 5 50	. .	. . .
39	Waltham, Mass.	1872	City.	Filter Basin.	Pumping.	Barr, Worthington.	Bituminous, Anthracite.	Pocahontas. Screenings.	4 35	12	. . .
40	Ware, Mass.	1886	Town.	Wells.	Pumping.	Deane, Warren.	Bituminous.	. . . .	5 00	. .	4 50
41	Wellesley, Mass.	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	Puritan, Georges Cr.	4 71	11	3 50
42	Westerly, R. I.	1886	Town.	Driven Wells.	Pumping.	Worthington.	Bituminous.	Georges Cr.	4 78	. .	6 00
43	Whitman, Mass.	1883	Town.	Silver Lake [Brockton W. W.]	Pumping.	Blake, Worthington.	. . . .	. . . .	. . . . .	. .	. . .
44	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake.	Bituminous.	. . . .	5 50	11	. . .
45	Woburn, Mass.	1872	City.	Filter Gallery.	Pumping.	Blake, Worthington.	Bituminous.	Carbon, New River.	5 63	9	. . .
46	Woonsocket, R. I.	1884	City.	Crook Falls Brook.	Pumping.	Worthington, Deane.	Bituminous.	Georges Cr., Pocahontas.	4 78	7	3 00
47	Yonkers, N. Y.	1874	City.	Streams and Wells.	Pumping.	Wright, Worthington, Wood.	Bituminous.	Georges Cr.	4 14	11	12 00

[1]Stations 1 and 2, water power.

1904.—TABLE 1, *Concluded.*—PUMPING STATISTICS.

	3	4	4a	5	6	7	8	9	10	11	12
Number.	Coal consumed for the year. (Lbs.)	Lbs. of wood ÷ 3 = equivalent coal.	Amount of other fuel used.	Total equivalent coal consumed for the year. (Lbs.)(3) + (4).	Total pumpage for the year in gallons.	Average static head against which pumps work. (Feet.)	Average dynamic head against which pumps work. (Feet.)	Number of gallons pumped per lb. of equivalent coal.	Duty in foot-pounds per 100 pounds of coal. No deductions.	Cost per million gallons pumped into reservoir, figured on pumping station expenses.	Cost per million gallons raised 1 foot high, figured on pumping station expenses.
2	5 458 459	3 000	....	5 461 459	1 626 721 780	95	126	298	30 916 015 [1]	$10 96	$0 087
	868 811	500	....	869 311	158 824 569	120	135	183	20 570 193	26 95	0 200
3	775 191	..	....	......	202 919 700	...	188	268	50 300 000	.....	.....
							225				
4	4 909 400	3 600	....	4 913 000	1 091 013 063 [2]	...	113	222	20 928 000	8 04	0 071
6	326 141	..	....	......	36 718 020 [2]	286	316	113	29 708 860	53 99	0 171
7	1 261 120	..	....	1 261 120	826 800 360 [2]	100	115	655	62 697 000	.....	.....
9	....	..	....	......	360 312 725	289	316	....	....	19 01	0 07
10	3 650 513	500	....	......	2 831 342 145 [2]	158	194	786	130 762 300	6 11	0 031
12	66 849 700	..	....	66 849 700	22 535 360 018 [2]	173	219	337	61 481 741	5 55	0 025
						326					
13	401 146	10 911	....	......	201 443 995	...	...	499	....	.....	.....
14	....	..	....	......	1 497 523 220	...	186	339	....	11 99	.....
16	1 909 598	500	....	1 910 098	1 015 701 696 [3]	182	201	700	89 261 119	10 22	0 051
								240			
19	243 761	..	....	......	78 001 236 [3]	290	318	325	85 771 219	11 34	0 096
	2 115 714	..	....	......	949 449 411	152	185	491	69 777 817		0 071
20	8 386 937	2 400	....	8 389 337	2 007 487 767	156 [4]	164 [4]	239	73 610 173 [4]	19 69 L	0 120 L
								538 [4]			
21	16 500	..	....	16 500	9 266 200 [3]	154	155	550	82 126 041	8 14	0 006
	3 531 500	320	....	3 531 820	1 943 952 500	151	153	562	79 193 335	.....	.....
22	1 762 300	..	....	......	547 834 400	201	231	....	....	31 05	0 131
23	735 400	..	....	......	221 262 300 [3]	164	173	301	43 410 616	13 33	0 077
*24a	1 012 902	..	....	......	576 200 000 [3]	...	121	568	65 400 000 [5]	7 17	0 059
b	279 676	..	....	......	292 860 000 [3]	...	128	1 017	120 540 000 [5]	4 53	0 035
c	8 656 737	..	....	......	10 522 750 000 [3]	...	129	1 215	134 950 000 [5]	2 81	0 022
d	8 662 868	..	....	......	20 268 940 000 [3]	...	55	2 340	110 290 000 [5]	1 67	0 030
e	2 462 802	..	....	......	2 927 470 000 [3]	...	129	1 189	132 070 000 [5]	4 05	0 031
25	634 250	..	....	......	93 227 000 [2]	182	204	147	25 007 913	28 27	0 11
26	6 958 959	..	13 983 [6] cords saw-dust, etc.	15 150 480	6 72 3 171 240	218	238	....	56 061 705 75 515 499 110 047 657 112 707 857	.....	.....

28	3 082 575	..	....	3 082 575	2 562 598 170[3]	167	185	831	128 277 825	$7 49	$0 045
30	3 649 240	6 000	....	3 655 240	799 765 400[2]	235	257	219	46 897 100	13 52	0 05
31	486 315	..	....	486 315	73 000 000[3]	80	84	150	10 520 000	29 22	0 35
32	326 890	..	....	......	121 212 352	65	73	371	23 386 577	15 13	0 207
	194 400				81 157 764			418			
33	7 015 400	667	....	7 016 067	3 576 092 908[3]	171	177	510	75 283 478		
	1 792 800	5 000	....	1 797 800	1 206 472 894	171	178	671	99 590 022	7 04	0 010
	1 189 590	2 484	....	1 192 074	556 620 531	115	130	467	50 142 014	16 38[7]	0 112[7]
	1 117 500	417	....	1 117 917	361 793 205	167	177	324	47 768 443		
34	466 820	..	....	......	56 279 377	219	240	120	24 131 106	64 60	0 269
35	5 874 700	1 800	....	5 876 500	1 473 045 733[2]	213	266	251	55 567 200	8 88	0 033
38	1 206 000	..	....	......	642 538 734	...	...	....	....	.....	.....
	406 400				547 832 019	...	69	....	30 616 902	12 05	0 174
39	1 327 685	..	....	......	758 640 923[2]	164	180	608	97 241 220	10 63	0 059
								270			
40	655 509	1 500	....	657 009	128 199 820[2]	221	244	195	39 705 922	24 66	0 10
41	663 814	317	....	664 131	114 689 955	260	280	172	40 325 433	26 22	0 91
42	1 400 928	782	....	1 401 710	250 957 400[3]	195	210	179	31 356 000	22 70	0 108
43	491 291	..	....	......	59 666 710	...	...	....	....	.....	.....
44	273 114	..	....	273 114	32 222 281[3]	246	289	143	33 941 887	36 40	0 12
45	1 962 500	..	....	......	520 284 450[2]	196	214	265	47 360 545	15 86	0 074
46	1 682 050	354	....	1 682 404	400 271 615[3]	239	240	238	47 624 693	13 79	0 057
47	6 100 856	..	....	......	2 023 809 108[2]	185	218	268	60 311 697	12 45	.....

[1] Part of supply pumped twice.
[2] Without allowance for slip.
[3] With allowance for slip.
[4] West Sixth Street Station.
[5] Figured on plunger displacement.
[6] 1 cord sawdust equivalent to 585.8 lbs. coal.
[7] H. S., pumped twice.

*24*a*. C. H. H. S. Station, engines 1 and 2.
b. C. H. H. S. Station, engine 3.
c. C. H. H. S. Station, engine 4.
d. C. H. L. S. Station, engines 5, 6, and 7.
e. Spot Pond Station, engine 9.

1904.—TABLE 2.—FINANCIAL STATISTICS.

Number.	Name of city or town.	Receipts. Balance brought forward. *a* From ordinary receipts.	Balance brought forward. *b* From extraordinary rec'pts.	Water rates. A Fixture rates.	Water rates. B Meter rates.	C Total from consumers.	Municipal departments. D For hydrants.	Municipal departments. E For fountains.
1	Arlington, Mass.	$40 375 77	....	$34 346 00	$4 686 60	$39 032 62	......	......
2	Atlantic City, N. J.	85 380 97	$67 139 39	....	....	124 601 19	......	......
3	Attleboro, Mass.	....	6 036 93	....	....	31 218 03	......	......
4	Bay City, Mich.	10 803 01	....	9 378 75	16 625 64	26 004 39	......	......
5	Belmont, Mass.	1 382 81	104 14	....	14 006 23	14 006 23	......	......
6	Billerica, Mass.	....	....	1 400 19	2 192 47	3 592 66	$2 300 00	......
8	Brockton, Mass.	....	52 405 28	3 022 03	89 637 56	92 659 59	3 000 00	......
9	Burlington, Vt.	....	....	7 262 77	37 836 83	15 099 60	3 560 00	......
10	Cambridge, Mass.	....	....	....	....	312 483 02	......	......
11	Chelsea, Mass.	....	....	83 778 32	30 182 07	113 960 39	......	......
12	Cleveland, Ohio	354 368 62	....	268 932 26	507 525 36	776 457 62	......	......
13	Concord, N. H.	....	....	29 248 28	38 522 23	....	......	......
14	Fall River, Mass.	138 261 85	....	2 775 38	178 381 38	....	......	......
15	Fitchburg, Mass.	....	....	19 714 40	47 000 87	....	......	......
16	Haverhill, Mass.	552 69	....	81 168 21	19 852 47	101 020 68	......	......
17	Holyoke, Mass.	11 601 46	....	81 902 71	25 769 84	107 672 55	......	......
18	Keene, N. H.	....	....	....	....	25 507 77	5 850 00	$350 00
19	Lawrence, Mass.	....	....	....	....	115 974 61	......	......

20	Lowell, Mass.	$3 059 92	....	$36 153 69	$138 121 52	$174 275 21	......	......
21	Lynn, Mass.	....	....	110 890 67	103 824 10	214 714 77	......	......
22	Madison, Wis.	1 358 17	....	....	....	26 465 77	......	......
23	Marlboro, Mass.	1 502 76	....	14 317 30	25 100 12	36 747 42	$6 760 00	......
25	Middleboro, Mass.	2 830 89	$151 42	3 555 94	7 408 27	10 964 21	......	......
28	New Bedford, Mass.	4 696 37	43 770 36	77 121 73	52 313 16	129 134 89	......	......
29	New London, Conn.	$3 02	1 22	....	....	61 428 20	......	......
30	Newton, Mass.	....	....	2 640 00	112 725 00	115 365 00	......	......
31	Oberlin, Ohio	....	....	653 35	8 741 25	9 397 60	......	......
32	Plymouth, Mass.	....	2 456 52	....	....	27 867 32	......	......
34	Reading, Mass.	75 93	337 95	....	10 161 10	10 161 10	4 890 00	$300 00
35	Reading, Pa.	24 654 83	....	141 165 55	49 003 36	193 168 91	......	......
36	Somerville, Mass.	....	....	155 476 73	60 550 61	216 027 34	......	......
37	Springfield, Mass.	11 846 19	....	152 148 99	92 618 78	214 767 77	20 320 00[1]	1 927 00[1]
38	Taunton, Mass.	....	2 628 01	....	....	65 319 15	......	......
39	Waltham, Mass.	4 061 10	6 111 80	56 871 67	15 724 58	72 596 25	......	......
40	Ware, Mass.	2 830 30	148 39	....	9 424 33	....	1 000 00	171 15
41	Wellesley, Mass.	4 891 36	....	....	18 095 26	18 095 26	(— —	3 500 00
42	Westerly, R. I.	6 227 42	....	2 756 10	26 199 42	28 955 52	3 133 34	......
43	Whitman, Mass.	....	1 371 32	2 212 25	6 152 38	8 361 63	2 780 00	......
44	Winchendon, Mass.	1 026 37	81 01	62 61	5 894 20	5 956 81	4 520 00	305 00
45	Woburn, Mass.	....	....	36 112 63	8 937 67	45 050 30	......	275 00
46	Woonsocket, R. I.	....	....	2 527 05	61 547 35	61 074 40	16 945 00	2 704 82
47	Yonkers, N. Y.	4 668 84	34 132 27	....	....	151 345 40	21 110 00	

[1] Book account only.

1904.—TABLE 2, *Continued.*—FINANCIAL STATISTICS.

RECEIPTS—*Continued.*

Number	Municipal departments—*Continued.* F For street watering.	G For public buildings.	H For miscellaneous uses.	I General appropriation.	J Total from departments.	K From tax levy.	L From bond issue.	M From other sources.	N Total receipts.
1	....	....	....	....	....	....	$3 500 00	$2 195 38	$55 503 75
2	$3 118 48	....	....	....	....	$11 000 00	....	1 027 78 5 152 82	327 723 63
3	....	....	....	....	....	3 000 00	22 112 89	276 27	....
4	....	....	....	....	....	18 130 00	19 000 00	356 75 782 04	75 376 19
5	....	....	....	....	....	....	5 500 00	565 18	21 598 66
6	....	$100 36	....	....	$2 400 36	2 369 45	....	29 10	8 391 87
8	1 000 00	....	....	....	1 000 00	....	190 000 00	2 871 58 14 756 85	....
10	....	....	....	....	....	....	....	....	353 828 07
11	....	....	....	....	....	....	....	1 705 16	115 665 55
12	....	....	....	....	....	....	399 095 33	64 569 97	1 594 491 51
14	....	....	....	....	....	....	20 000 00	9 197 69	....
15	....	....	....	....	....	....	....	5 368 95	72 081 22
16	....	....	....	....	....	....	....	13 795 01	115 368 38
17	....	....	....	....	....	....	....	6 300 90	125 574 91
18	1 500 00	200 00	....	....	7 900 00	....	....	....	33 107 77
19	....	....	....	....	....	....	....	....	115 974 61
20	1 200 00	5 500 00	....	....	6 700 00	17 800 00	....	16 098 43	217 933 56
21	....	....	....	....	....	....	99 213 58	10 104 72	324 333 07

22	....	....	....	....	....	$10 000 00	$20 362 89	?	$60 081 15
23	....	$235 90	$22 73	....	$7 018 63	....	1 076 00	$2 323 97	48 668 78
25	....	....	....	$1 500 00	1 500 00	....	....	204 11 357 97	....
28	....	....	....	12 000 00	12 000 00	67 480 00	....	....	227 381 62
29	....	....	....	....	....	....	....	....	....
30	$3 000 00	2 858 00	....	....	5 858 00	....	37 801 15	9 053 00 4 605 06	....
31	....	....	....	....	....	3 510 00	....	883 53	13 751 03
32	....	....	....	....	....	3 500 00	1 440 00	1 295 52	....
34	500 00	....	....	....	5 690 00	1 300 00	....	764 18	18 329 46
35	....	....	....	....	....	....	....	9 316 68	227 140 42
36	....	....	....	....	....	....	....	8 081 60	224 108 94
37	6 269 58[1]	13 363 99[1]	....	....	41 880 57[1]	....	....	684 00[1] 266 541 89 107 57	321 030 22
38	....	855 54	....	....	....	15 000 00	....	15 058 80 826 60	....
39	....	....	469 02	....	469 02	....	....	4 526 40	87 791 57
40	....	484 30	365 29	....	....	2 700 00	....	515 73	....
41	———)	212 60	115 00	....	3 827 60	....	3 000 00	2 044 85	31 859 07
42	....	....	....	....	3 433 31	....	2 021 51	3 943 69	41 581 48
43	....	....	....	....	....	2 000 00	20 000 00	....	....
44	126 90	....	....	....	4 951 90	2 500 00	....	....	14 516 09
45	250 00	255 00	....	....	780 00	....	....	116 14 911 89	....
46	2 642 82	1 189 76	559 18	1 500 00	39 081 58	....	....	32 45	103 188 43
47	....	....	....	....	....	....	159 541 00	2 314 11	....

[1] Book account only.

1904.—TABLE 2. *Continued.*—FINANCIAL STATISTICS.

Number.	Maintenance Expenditures. AA Operation.	BB Special.	CC Total maintenance.	DD Interest on bonds.	EE Payment of bonds.	FF Sinking fund.	Construction Expenditures. GG Extension of mains.	HH Extension of services.	II Extension of meters.	JJ Special.	KK Total constr'tion.
1	$6 565 26	$12 972 76[1]	$19 538 02	$12 760 00	......	$10 000 00	$3 217 31	$817 37	$229 20	......	$4 263 91
2	56 137 82	....	....	57 999 50	......	31 500 00	15 778 28	2 195 11	2 310 19	$50 553 77	70 867 65
3	....	....	17 245 92	13 645 00	......	5 500 00	......	.....	.....	....	21 056 87
4	15 551 33	....	15 551 33	18 130 00	$19 000 00	....	10 697 29	.....	783 21	......	14 180 50
5	1 688 09	6 391 85[1]	....	1 660 00	2 250 00	520 00	6 269 61	697 59	288 62	....	7 255 82
6	....	....	2 892 00	3 600 00	......	1 800 00	......	.....	.....	....	99 87
8	30 713 52	....	....	50 722 50	......	....	37 242 02	3 152 88	2 726 33	161 811 01	204 932 27
9	28 906 43	....	....	9 920 00	......	....	2 387 99	112 01	.....	....	....
10	....	....	97 845 40	126 126 50	......	121 522 50	......	.....	3 999 42	....	21 851 98
11	12 455 25	44 507 49[1]	56 962 74	12 000 00	......	5 410 00	......	.....	.....	....	3 578 11
12	371 032 03	2 100 00	373 132 03	149 500 00	......	....	278 330 24	.....	88 271 21	245 070 69	611 672 14
14	56 363 25	....	....	92 747 50	125 000 00	....	......	.....	.....	11 637 29 20 000 00	....
15	37 998 82[2]	....	....	......	......	....	......	.....	.....	....	....
16	20 806 74	....	20 808 74	39 640 00	5 000 00	18 000 00	3 822 74	5 504 03	473 41	829 82	10 630 00
17	32 481 27	3 263 57	35 744 84	13 750 00	......	5 600 00 21 243 06	1 808 82	.....	723 40	37 677 20	40 209 42
18	....	....	2 651 02	3 970 00	......	....	......	.....	.....	....	....
19	....	....	59 352 09	32 080 00	......	15 429 00	8 598 48	2 366 13	[3]	46 30	11 010 16
20	88 357 69	....	88 357 69	45 631 00	21 600 00	17 800 00	8 843 67	4 899 43	2 328 79	....	16 071 59

21	$108 327 61	....	$108 327 61	$85 791 88	......	$31 000 00	......	$9 048 62	.....	$83 728 16	$92 776 78
22	....	....	3 220 18	......	......	....	......	.....	.....	....	21 989 48
23	8 998 66	$225 99	16 911 69 9 224 65	20 760 00	......	....	......	.....	.....	....	3 621 37
25	5 053 33	....	5 053 33	1 940 00	......	5 000 00	$310 07	580 16		....	890 53
28	49 024 16	....	49 024 16	72 480 00	$30 000 00	44 000 00	19 976 23	5 578 37	$2 379 99	2 403 78	30 338 37
29	9 591 71	498 61	10 090 35	21 915 35	......	....	11 196 13	2 728 87	1 093 76	14 925 61	29 944 37
30	19 981 00	....	....	101 315 00	......	....	13 210 88	8 526 45	2 980 76	13 105 44	42 406 21
31	5 142 74	....	5 142 74	1 778 06	2 000 00	....	376 14	620 81	813 77	4 582 68 1 972 28 287 69	4 070 69
32	11 899 36	....	....	4 730 80	8 306 66	....	9 972 04	307 85	.....	6 949 35	17 229 24
34	6 037 71	735 96	6 773 67	8 425 00	......	....	934 00	1 475 96	331 83	362 55	3 104 34
35	55 485 97	1 515 24	57 001 21	15 700 00	......	11 500 00	15 811 73	.....	3 761 40	2 220 01 39 934 42 56 624 71	118 352 27
36	25 665 40	86 736 93[1] 3 324 89	....	4 850 00	15 000 00	....	8 490 48	3 880 99	10 448 06	162 95	22 982 48
37	32 869 74	31 150 55 213 83 18 970 65	....	36 675 00	......	112 508 44	6 163 18	.....	.....	25 981 20	32 144 38
38	29 458 64	....	....	33 693 00	......	3 024 41	23 552 08	1 711 33	1 084 13	5 336 45	31 683 99
39	30 713 81	....	30 713 81	17 605 00	......	25 000 00	......	.....	.....	....	9 121 71
40	9 741 33	....	....	......	......	....	......	.....	.....	....	4 248 39
41	7 088 28	67 30	7 150 58	11 280 00	......	....	2 831 43	696 75	596 09	....	4 121 27
42	9 675 56	....	9 675 56	12 357 92	......	2 251 20	5 697 14	2 326 46	1 527 79	......	9 551 39
43	....	....	4 985 21	4 000 00	......	2 000 00	......	.....	.....	....	23 277 14
44	4 267 35	....	4 267 35	3 500 00	2 000 00	....	1 936 37	377 96	361 46	1 171 58	3 853 37
45	16 916 60	....	....	1 652 00	......	27 687 28	......	602 95	.....	....	602 95
46	15 371 84	....	....	38 280 00	......	....	......	18 101 89	.....	....	....
47	71 354 81	....	....	84 113 84	......	24 000 00	......	.....	.....	....	214 361 44

[1] Metropolitan water-works assessment.

[2] Including extension of mains.

[3] Charged to Maintenance.

1904. TABLE 2, *Concluded.* — FINANCIAL STATISTICS.

Number.	LL. Unclassified expenses.	MM. Balance. *aa* Ordinary.	MM. Balance. *bb* Extraordinary.	N. Total.	Disposition of balance.	O. Net cost of works to date.	P. Bonded debt at date.	Q. Value of sinking fund.	R. Average rate of interest. Per cent.
1	......	$8 559 16	$282 66	$55 403 75	Forward.	$498 000 00	$322 000 00	$19 000 00	4
2	......	94 333 01	16 585 62	327 723 63	Forward.	1 370 194 31	1 244 000 00	211 806 92	4¼
3	......	......	5 256 33	......	......	172 910 70	337 000 00	35 397 67	......
4	......	10 914 36	......	75 376 19	......	644 606 36	342 000 00	......	5.4
5	......	4 138 77	394 13	......	......	......	39 250 00	4 390 69	4
6	......	......	......	8 394 87	......	92 320 28	90 000 00	14 572 61	5
8	......	18 098 15	52 229 86	......	......	1 532 501 89	1 415 000 00	509 135 02	3.6
9	......	8 210 35	......	......	......	183 600 65	218 000 00	53 000 00	4
10	$7 291 63	......	......	374 638 01	......	5 772 507 13	3 350 600 00	1 218 686 74	3½ to 4
11	567 27	37 147 13	......	115 665 55	City Treasury.	199 142 32	300 000 00	82 607 00	4
12	3 058 26	157 129 14	......	1 594 491 51	Forward.	9 530 162 00	3 950 000 00	0	4
14	......	12 868 26	......	......	......	2 032 448 21	1 975 000 00	$12 631 45	4.7
15	......	34 096 40	......	72 084 22	City Treasury.	121 380 78	567 000 00	145 619 22	......
16	......	21 291 21	......	115 368 38	......	1 401 167 03	986 000 00	240 951 53	4
17	1 816 77	7 210 82	......	125 574 91	......	1 295 308 26	350 000 00	71 587 95	......
18	......	26 786 75	......	33 407 77	City Treasury.	......	......	......	......
19	......	......	......	117 871 70[1]	......	2 231 340 42	752 000 00	66 053 27	5
20	9 637 96	18 835 32	......	217 933 56	Forward.	2 996 402 05	1 075 000 00	406 430 22	4

21	....	....	$6 436 80	$324 333 07	Forward.	$2 900 890 89	$2 160 000 00	$746 585 78	4
22	....	$17 959 80	....	60 084 15	....	414 281 78	37 500 00	....	3¾ to 4
23	....	15 062 26	....	48 668 78	....	591 343 90	519 000 00	198 072 31	4
25	....	3 121 74	....	....	....	118 987 88	45 500 00	13 967 34	4
28	....	1 542 09	....	227 381 62	Forward.	3 261 678 78	1 638 000 00	292 016 99	4.34
29	$35 000 00	(62 249 70)		....	....	980 250 93	601 000 00	....	3.59
30	....	8 980 00	....	....	....	2 189 775 31	2 185 000 00	1 150 335 00	4.6
31	964 41	—201 87	....	13 751 03	....	112 644 96	—49 000 00	....	3.8
32	....	....	....	....	....	355 318 21	117 173 14	....	3½ to 4
33	....	....	....	....	....	6 638 894 92	5 674 000 00	1 409 326 60	3.85
34	....	(26 45)		18 329 46	Forward.	289 811 96	209 000 00	....	4
35	1 306 98	23 279 96	....	227 140 42	Forward.	2 324 191 57	400 000 00	32 690 57	4
36	982 91	61 566 33	....	244 108 94	City Treasury.	838 706 95	108 000 00	....	4
37	41 791 90	14 705 73	....	320 922 65	....	2 278 678 57	835 000 00	194 192 15	4.31
38	....	....	1 002 82	....	....	1 324 509 96	842 200 00	288 871 57	3½ to 4
39	....	3 807 56	1 246 49	87 794 57	....	632 753 51	455 000 00	221 335 26	3.88
40	....	3 317 07	191 26	....	....	141 765 03	30 600 00	....	3½ to 4
41	3 852 35[2]	4 768 82	683 05	31 859 07	Forward.	339 530 87	284 000 00	123 787 30	4
42	....	....	....	....	Forward.	369 482 64	353 000 00	51 191 18	3¾
43	....	....	2 608 85	....	....	157 689 89	120 000 00	18 173 03	4
44	....	835 37	....	14 516 09	....	129 671 56	87 000 00	....	4
45	....	....	....	....	....	603 668 99	19 700 00	....	4
46	....	596 08	....	72 349 81	....	224 212 89	982 000 00	429 020 89	3.8
47	....	....	—20 688 17	....	....	1 994 671 57	1 760 000 00	358 894 69	5.33

[1] Excess over receipts to be raised by direct taxation in ensuing year.

[2] Paid into town treasury.

1904. — TABLE 3. — STATISTICS OF CONSUMPTION OF WATER.

Number.	Name of city or town.	1	2	3	4	5	6	7	8	9	10	11	12
		Estimated population.			Total consumption for the year. (Gallons.)	Quantity used through meters. (Gallons.)	Percentage of consumption metered.	Average consumption. (Gallons per day.)				Cost of supplying water. Per million gallons.	
		Total at date.	On line of pipe.	Supplied at date.				Total.	To each inhabitant.	To each consumer.	To each tap.	Figured on total maintenance. (Item CC.)	Figured on total maintenance + interest on bonds.
1	Arlington, Mass.	9 700	9 500	9 400	275 410 000	32 526 630	12	752 567	78	80	420	....	....
2	Atlantic City, N. J.	38 000	37 500	125 000[1]	1 785 561 349	....	..	4 870 000	128	..	990	$32 59	$72 30
								6 798 000[1]					
3	Attleboro, Mass.	13 500	13 000	....	202 919 700	....	..	551 513	41	43	..	....	....
4	Bay City, Mich.	29 000	22 000	18 500	1 091 013 061	234 997 513	22	2 980 910	100	161	1 200	11 26	31 15
5	Belmont, Mass.	4 500	4 300	4 100	....	50 877 000	..	248 800[2]	31[3]	34[3]	207[3]	....	....
								139 300[3]					
6	Billerica, Mass.	2 850	1 900	1 550	36 718 020	....	..	109 472	..	61	..	78 76	176 18
7	Bridgeport, Conn.	85 000	83 000	82 000	6 385 500 000	1 399 500 000	17	17 500 000	206	213	1 721	....	....
8	Brockton, Mass.	48 000	46 500	43 600	591 371 442	307 668 842	52	1 615 768	34	37	266	....	....
9	Burlington, Vt.	19 700	19 200	19 100	360 312 725	205 935 487	57	987 158	50	51	270	....	....
10	Cambridge, Mass.	97 826	97 826	97 826	3 210 982 145	1 143 795 390	36	8 773 175	90	90	593	21 39	65 95
11	Chelsea, Mass.	36 199	36 499	36 499	1 559 343 000	192 066 032	12	4 260 500	117	117	670	36 53	11 23
12	Cleveland, Ohio	455 000	450 000	444 600	22 535 360 018	8 859 446 640	39	61 572 022	137	138	1 016	16 56	23 19
13	Concord, N. H.	....	17 000	....	....	....	..	....	..	..	..	....	....
14	Fall River, Mass.	113 645	...	112 045	1 497 523 220	....	..	4 091 593	36	37	..	....	....
15	Fitchburg, Mass.	34 000	...	29 000	1 006 000 000[4]	....	..	2 750 000[4]	..	95[4]	..	....	....
16	Haverhill, Mass.	39 000	37 500	37 000	1 500 000 000[4]	....	..	4 109 590[4]	105	111	728	13 86	40 29
17	Holyoke, Mass.	51 406	51 106	50 831	2 664 500 000[4]	498 616 500	19	7 300 000[4]	142	114	1 941	....	....
18	Keene, N. H.	10 000	9 500	9 000	....	....	..	....	..	..	..	....	....
19	Lawrence, Mass.	72 000	...	68 500	1 027 450 650	608 250 750	59	2 814 933	39	42	427	57 79	89 03
20	Lowell, Mass.	104 400	...	104 400	2 007 628 279	875 780 355	44	5 485 323	53	53	486	44 01	66 74
21	Lynn, Mass.	83 500	82 500	82 500	1 952 018 566	550 000 000	25	5 333 384	64	65	365	48 00	100 00
22	Madison, Wis.	21 000	...	20 772	547 834 400	156 931 222	29	1 501 053	52	..	433	....	....
23	Marlboro, Mass.	14 300	13 800	13 200	221 262 300	91 474 500	41	606 198	42	46	262	40 66	134 50
24	Met. W'r Dist., Mass.	927 800	...	....	42 057 180 000	....	..	114 909 000	124	..	..	....	....
25	Middleboro, Mass.,	7 000	4 200	3 900	93 227 000	42 064 665	45	255 416	61	65	289	....	....
	Fire Dist.,	4 500											
26	Minneapolis, Minn.	240 000	200 000	190 000	6 632 236 620	1 900 000 000	29	18 269 320	77	..	..	....	....
27	Nashua, N. H.	26 000	25 000	25 000	1 076 588 509	....	..	2 941 499	..	..	..	29 18	....
28	New Bedford, Mass.,	73 000	64 000	63 000	2 570 360 614	762 810 000	30	7 001 520	96	111	689	19 07	47 27
29	New London, Conn.,	22 000	20 800	20 000	585 600 000	....	..	1 600 000	78	80	446	17 23	54 65

30	Newton, Mass.	39 100	38 500	38 300	800 888 053	512 000 000	64	2 188 219	56	57	292	....	....
31	Oberlin, Ohio	4 800	4 000	3 000	60 000 000	29 147 000	49	165 000	34	55	200	$85 70	$115 35
33	Providence, R. I.	207 900	...	207 900	5 071 693 691	....	60[4]	13 857 087	67	67	580	....	....
34	Reading, Mass.	5 000	4 860	4 553	56 279 377	....	..	154 190	31	34	130	120 37	270 05
35	Reading, Pa.	88 760	88 500	88 670	4 031 675 218	1 053 737 190	26	11 046 000	124	125	587	14 14	18 03
36	Somerville, Mass.	71 000	71 000	71 000	2 279 637 000	416 097 066	18	6 228 000	89	89	..	....	....
37	Springfield, Mass. (incl. Ludlow.)	76 220	75 000	74 916	3 557 520 000	636 850 245	18	9 720 000	128	130	913	....	....
38	Taunton, Mass.	31 036	28 000	27 500	612 538 734	235 812 251	37	1 755 201	57	64	363	45 85	98 28
39	Waltham, Mass.	26 600	26 350	26 300	758 610 923	77 121 747	10	2 072 789	78	79	591	40 48	63 70
40	Ware, Mass.	8 263	7 974	7 850	128 199 820	82 401 541	64	351 232	44	45	432	....	....
41	Wellesley, Mass.	5 793	5 738	5 700	114 689 955	60 245 923	53	314 219	54	55	331	62 34	160 69
42	Westerly, R. I.	13 500	12 000	11 000	250 954 400	....	..	687 500	57	62	449	38 55	87 80
43	Whitman, Mass.	6 781	...	....	....	....	..	....	..	..	..	....	....
44	Winchendon, Mass.	5 615	3 400	2 776	32 222 281	15 456 247	48	88 280	16	33	138	125 52	230 21
45	Woburn, Mass.	14 250	14 200	14 200	520 284 450	67 226 077	13	1 413 108	100	..	468	....	....
46	Woonsocket, R. I.	36 974	36 474	36 474	399 795 790	299 006 808	75	1 092 338	30	30	413	38 45	134 20
47	Yonkers, N. Y.	60 000	59 000	59 000	2 023 809 108	1 100 884 303	55	5 529 531	91	94	937	....	....

[1] In summer. [2] Metropolitan water works measurement. [3] By meters; all services metered. [4] Estimated.

1904. — TABLE 4. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
										Hydrants.			Gates.			
Number.	Name of city or town.	Kind of pipe.	Sizes of pipes. (Inches.)	Length extended during the year. (Feet.)	Length discontinued during the year. (Feet.)	Total length in use. (Miles.)	Cost of repairs. (Per mile.)	Number of leaks. (Per mile.)	Length of pipe less than 4 ins. diam. (Miles.)	Number added.	Total in use.	Number added.	Total in use.	Number smaller than 4-inch.	Number of blow-off gates.	Range of pressure on mains. (Pounds.)
1	Arlington, Mass.	C. I., Cem. L.	4–12	1 838	....	35.5	$5.90	..	0.76	6	357	3	295	...	.	90–50
2	Atlantic City, N. J.	C. I.	4–20	11 365	1 023	60.1	...	..	2.92	13[1]	633[1]	41	....	...	4	40–55
3	Attleboro, Mass.	C. I., Cem. L., W. I.	1–16	6 128	....	41.8	...	0.8	..	6	335	...	....	...	...	51–62
4	Bay City, Mich.	C. I., Wyckoff.	4–20	11 090	9 546	48.4	27.27	1.9	..	8	451[1]	17	771	...	12	35–80
5	Belmont, Mass.	C. I.	4–12	7 663	....	20.1	0	0	0.5	11	158	16	219	21	12	15–100
6	Billerica, Mass.	C. I.	6–12	....	....	9.7	...	2.8	..	..	103	..	81		4	51–120
7	Bridgeport, Conn.	C. I., Cem. L.	4–30	14 536	573	143.6	...	..	0	10	682	30	1 110	0	35	30–50
8	Brockton, Mass.	C. I., Cem. L., W. I.	6–30	34 941	270	92.4	3.31	0.3	1.7	34	786	65	1 011	30	11	17–56
9	Burlington, Vt.	C. I., Cem. L., W. I.	4–30	7 901	6 740	40.0	9.53	0.2	3.8	1	216	22	673	66	11	70–85
10	Cambridge, Mass.	C. I.	2–40	1 412	....	125.6	...	17.0	2.0	13[1]	1 018[1]	23	....	0	...	15–55
11	Chelsea, Mass.	C. I.	2–16	792	....	38.7	...	..	0.1	1	299	6	428	0	33	50–75
12	Cleveland, Ohio	C. I.	3–48	83 257	11 903	607.0	11.63	0.4	2.0	207	7 065	396	13 273	6	...	12–63
13	Concord, N. H.	C. I., Cem. L.	4–24	20 923	5 632	65.1	...	..	..	10	292	23	840	...	...	.....
14	Fall River, Mass.	C. I.	6–24	....	....	96.9	...	..	..	31	1 091	41	1 091	...	...	80
15	Fitchburg, Mass.	C. I.	2–30	13 110	....	71.6	...	..	..	44	573	62	643	...	...	155 75
16	Haverhill, Mass.	C. I., Cem. L.	2–24	4 294	....	80.5	...	..	..	2	340	17	848	...	...	30–120
17	Holyoke, Mass.	W. I., C. I., Ld. L.	½–30	1 171	....	85.6	3.12	0.1	5.7	19	815	10	820	15	36	45–100
18	Keene, N. H.	W. I., Cem. L., C. I.	4–24	1 860	....	40.3	2.40	1.7	3.1	6	245	7	390	...	31	55–60
19	Lawrence, Mass.	C. I.	1–30	5 116	2 084	84.7	...	..	7.8	12[1]	790	28	1 103	...	11	65–125
20	Lowell, Mass.	C. I.	4–30	5 706	....	133.7	...	..	2.0	11	1 212	26	1 331	25	31	17–72 L. S.
21	Lynn, Mass.	C. I., Cem. L.	4–36	754	....	135.0	...	1.6	..	2	965	17	1 019	...	66	40–60
22	Madison, Wis.	C. I.	4–8	20 649	....	42.9	...	..	..	36	236	32	307	...	2	53–65
23	Marlboro, Mass.	C. I.	4–16	0	0	36.6	2.62	0.2	0.9	1	347	0	390	19	65	35–142
	Met. Water Works	C. I., Cem. L.	6–60	....	....	84.2	...	..	..	..	....	3	356	...	...	.....
24	Met. Water Dist., (belonging to municipalities)	C. I., Cem. L., Kal.	4–60	....	....	1507.8	...	..	..	178	13 289	..	....	...	...	.....
25	Middleboro, Mass.	C. I.	4–12	542	0	17.3	...	..	0	2	123	2	180	0	6	40–60
26	Minneapolis, Minn.	C. I., W. I., Steel.	6–50	88 933	9 286	301.7	...	0.3	..	173	3 585	117	2 599	...	41	.....
27	Nashua, N. H.	C. I.	4–24	....	....	.....	...	..	..	..	250	...	....	...	...	70
28	New Bedford, Mass.	C. I.	4–36	13 758	2 358	102.3	9.50	0.1	0.9	42	1 040	42	1 214	114	101	25–95

29	New London, Conn.	C. I., Cem. L.	4–24	7 377	0	61	$8 32	0 2	16 8	13	337	23	400	...	34	35–45
30	Newton, Mass.	C. I.	4–20	5 560	0	140 3	1 25	0 03	3 1	4	791	10	829	48	98	80–86
31	Oberlin, Ohio	C. I.	4–12	411	0	10 61	0	0	0 3	1	98	0	67	2	2	27–32
32	Plymouth, Mass.	Cem. L., W. I.	2–20	9 186	5 707	46 5	15 77	1 27	10 3	6	199	27	498	134	37	.....
33	Providence, R. I.	C. I.	6–36	22 767	2 291	345 7	...	0 05	0	42[1]	2 031[1]	68	3 674	0	32	64–73
	H. P. Fire Service	C. I.	12–24	109	....	5 6	...	..	..	0	92	...	31	...	4	114
34	Reading, Mass.	C. I.	6–12	951	0	28 7	1 30	0	0	1	164	1	249	0	14	63–78
35	Reading, Pa.	C. I.	1½–36	8 788	1 627	106 5	9 77	0 7	0 8	18[1]	858[1]	74	2 634	9	...	10–133
36	Somerville, Mass.	C. I.	4–20	5 826	....	89 5	2 53	0 07	..	15	1 033	24	1 343	...	135	35–100
37	Springfield, Mass.	Cem. L., W. I., C. I.	1–36	11 190	1 926	152 2	6 31	0 3	8 2	16[1]	1 016[1]	76	2 129	436	89	30–35 L. S. 90–120 H. S.
38	Taunton, Mass.	C. I.	4–20	1 220	0	80 8	0 21	0 3	1 5	24	837	21	600	12	60	35–120
39	Waltham, Mass.	C. I., Cem. L.	2–24	12 973	11 270	52 8	3 67	0 4	2 1	20	384	19	736	40	60	50–70
40	Ware, Mass.	C. I.	4–12	....	....	12 5	...	..	1	..	120	1	127	13	3	90–95
41	Wellesley, Mass.	C. I., Cem. L.	4–12	2 241	0	31 8	1 12	0 4	0 3	13	303	4	239	3	4	70–75
42	Westerly, R. I.	C. I.	4–16	7 488	0	33 8	...	0 2	..	2	155	7	208	...	8	82–92
43	Whitman, Mass.	C. I., Cem. L.	1–16	....	....	20 8	...	..	..	5	166	16	109	...	...	.....
44	Winchendon, Mass.	C. I., W. I.	2–11	1 921	0	18 2	...	..	1 9	1	142	7	189	29	19	40–151
45	Woburn, Mass.	C. I., Cem. L.	4–14	....	....	54 8	44 16	1 1	5 3	0	361	2	430	55	17	70–75
46	Woonsocket, R. I.	C. I.	4–20	5 572	0	50 0	3 60	0 1	0	15	595	16	501	0	15	50–120
47	Yonkers, N. Y.	C. I.	3–30	11 193	....	93 0	30 90	0 7	0 8	30	967	32	637	3	24	45–130

[1] Public hydrants only.

1904. — TABLE 5. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — SERVICE PIPES.

		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Service Pipe.					Service Taps.				Meters.				Motors & Elevators.	
Number.	Name of city or town.	Kind.	Sizes. (Inches.)	Extended. (Feet.)	Discontinued (Feet.)	Total in use. (Miles.)	Number added.	Total in use.	Average length of services. (Ft.)	Average cost of services for the year.	Number added.	Now in use.	Percentage of services metered.	Percentage of receipts from metered water. (B) ÷ (C)	Added.	Total in use.
1	Arlington, Mass.	Cem. Lined, G. I., C. I.	5/8–6	....	...	...	37	1 880	..	$22 10	6	116	6	12	..	5
2	Atlantic City, N. J.	Tin Lined, G. I.	1/2–4	922	...	...	84	4 903	11	9 80	52	3 981	81	..	..	7
3	Attleboro, Mass.	....	..	....	...	...	...	.....	..	....	99	1 666	..	..	..	2
4	Bay City, Mich.	Lead, W. I., C. I.	3/8–8	....	...	...	79	2 487	..	....	68	1 083	41	64	..	..
5	Belmont, Mass.	W. I., Cem. Lined, G. I.	1–6	1 726	...	6 6	30	673	65 6	21 50	30	673	100	..	..	..
6	Billerica, Mass.	W. I., Cem. Lined.	1–1½	1 336	...	3 6	12	268	71 1	....	9	151	56	70	..	..
7	Bridgeport, Conn.	Lead, W. I.	5/8–1	....	...	...	679	10 168	..	....	200	456[1]	..	..	..	..
8	Brockton, Mass.	W. I., Lead Lined, Cem. L., C. I.	3/4–8	13 817	1 324	40 8	248	6 097	52 9	12 08	200	5 199	90	97	2	12
9	Burlington, Vt.	Galv. I., C. I., Lead.	1/2–6	1 903	500	19 5	56	3 580	25	8 31	90	2 770	..	..	0	35
10	Cambridge, Mass.	Galv. I., C. I.	3/4–8	5 737	...	115 2	111	14 803	13	17 69	363	2 596	17	..	..	..
11	Chelsea, Mass.	Lead.	5/8–2	1 162	...	32 4	41	6 357	28	17 50	10	126	2	26	0	6
12	Cleveland, Ohio	....	..	....	...	...	1 775	60 627	16	....	5 196	30 226	49	65	—11	143
13	Concord, N. H.	....	..	1 303	...	15 2	50	3 458	..	....	65	1 337	39	..	..	..
14	Fall River, Mass.	Lead.	1/2–2	....	...	...	165	7 667	..	....	183	7 391	96	..	..	..
15	Fitchburg, Mass.	W. I., Cem. Lined, C. I.	3/4–8	....	...	...	73	4 766	..	....	84	2 796	..	..	3	110
16	Haverhill, Mass.	Lead, W. I.	1/2–2	2 640	...	43 5	66	5 641	10	16 00	33	688	12	20	..	18
17	Holyoke, Mass.	Cem., Rubber Lnd., Enam., C. I., Ld. Lnd., Tin Lnd., G. I.	1/2–1	980	...	14 2	50	3 760	20	15 00	1	218	7	..	3	109
18	Keene, N. H.	W. I., Cem. Lined, G. I., Lead.	3/4–6	1 200	...	11 1	30	1 889	..	....	11	120	6	..	..	10
19	Lawrence, Mass.	G. I., Lead, Ld. Lined, C. I.	3/4–10	5 089	603	51 0	111	6 581	39 8	21 31	141	5 714	87	93	..	19
20	Lowell, Mass.	Ld., Ld. Lnd., W. I., Tin Lnd.	5/8–2	6 638	...	81 4	178	11 287	39 5	27 52	277	7 513	64	79	..	..
21	Lynn, Mass.	Cem. Lined, Ld. Lnd.	1/2–4	10 817	418	102	260	13 427	10	18 00	194	3 732	25	23	..	..
22	Madison, Wis.	Lead.	5/8–1¼	2 807	...	17 2	145	3 462	..	....	160	3 336	97	..	..	..
23	Marlboro, Mass.	Cem. Lnd., Ld. Lnd., Lead, G. I.	3/4–2	244	0	9 2	11	2 271	21	12 40	44	1 310	50	69	1	12
24	Met. W'r Dt., Mass.	....	..	....	...	...	1 343	145 861	..	....	882	15 246	10	..	..	..
25	Middleboro, Mass.	Cem. Lined, W. I., Ld.	1/2–2	1 209	0	9 9	16	883	58	....	15	399	45	59	0	7
26	Minneapolis, Minn.	Lead, G. I.	5/8–1	....	...	...	...	26 444	..	....	1 954	11 011	42	..	..	8
27	Nashua, N. H.	G. I.	3/4–2	....	...	...	...	.....	..	....	...	614	..	..	..	..
28	New Bedford, Mass.	Lead, C. I.	1/2–10	12 120	634	67 0	239	10 166	34 8	21 29	191	2 145	21	40	3	135
29	New London, Conn.	Cem. Lined, G. I., Lead.	1/2–4	2 631	190	11 2	136	3 589	19 2	11 82	10	288	8	..	0	6
30	Newton, Mass.	G. I., Tarred I., Lead.	3/4–6	10 030	3 889	83	82	7 486	59	25 02	114	6 435	86	98	0	17
31	Oberlin, Ohio	G. I., Lead.	3/4–4	....	...	...	54	854	25	9 00	44	556	80	93	0	0

32	Plymouth, Mass.	Lead, Cem. Lined.	½–4	672	...	6 5	41	2 151	16	7 50	..	....	..	..	0	1
33	Providence, R. I.	Lead, C. I.	½–10	....	...	...	587	23 881	..	....	688	20 489	86	..	5	181
34	Reading, Mass.	Lead, Cem. Lined, C. I.	¾–6	3 477	72	16 0	27	1 189	128	54 66	14	1 049	88	100	..	4
35	Reading, Pa.	Lead, W. I., Ld. Lined, C. I.	½–8	....	...	...	726	18 830	..	....	156	1 293	7	25	2	12
36	Somerville, Mass.	Lead, Ld. Lined, Cem. Lined.	½–6	7 606	...	70 7	201	11 059	..	19 31	624	1 262	11	28	1	10
37	Springfield, Mass.	Ld., Cem. Lined, Tarred Iron, G. I., C. I.	½–6	....	...	...	170	10 641	..	....	189	3 987	..	..	8	288
38	Taunton, Mass.	Cem. Lined, Tin Lined.	¾–3	3 369	...	46 8	73	4 837	..	....	65	2 199	15	66	2	19
39	Waltham, Mass.	W. I., C. I.	¾–12	7 902	2 225	42 7	68	3 508	78	36 40	40	340	10	22	0	10
40	Ware, Mass.	W. I., Cem. Lined.	1–2	1 009	21	10 1	18	816	62	....	19	819	94	100	1	10
41	Wellesley, Mass.	Cem. Lined, Lead Lined, C. I.	½–8	6 106	98	17 4	31	949	185	16 25	42	951	100	100	0	0
42	Westerly, R. I.	Lead, Iron.	½–4	3 155	0	...	73	1 530	43	12 24	91	1 272	83	..	0	11
43	Whitman, Mass.	....	..	....	...	...	35	1 093	..	....	...	545	..	..	..	..
44	Winchendon, Mass.	W. I.	1–2	1 617	0	5 0	36	569	46	10 50	35	518	97	99	1	1
45	Woburn, Mass.	Lead Lined, Cem. Lined.	1	....	...	...	25	3 021	..	24 12	1	65	2	20	.	9
46	Woonsocket, R. I.	Lead, C. I.	⅝–6	1 343	0	7 7	106	2 633	13	12 46	96	2 248	85	96	2	15
47	Yonkers, N. Y.	Lead, C. I.	⅜–8	....	...	...	231	5 948	..	....	249	5 891	100		.	11

[1] Meters on factories only.

TESTS OF LARGE METERS AND FIRE-SERVICE DEVICES.

BY WILLIAM F. SULLIVAN, ASSISTANT ENGINEER, LOWELL, MASS.

[*Read March 8, 1905.*]

In studying the water statistics of large cities one is compelled to ask himself, " Where does the water go? "

No particular attention was given to answering this question until the advent of water sanitation or until, in many places, the purification of a water supply, or new sources of supply became necessary, with consequent increased cost of maintenance. The installation of more expensive systems has made this question, " Where does the water go? " of much importance to water-works managers and water-works people generally. They have come to see the need of detecting small or large wastes. The first real reform in this direction was the metering of house services.

Cities having a large percentage of small taps metered continued to find a discrepancy between the water recorded and accounted for and the total consumption. This being a fact, the next step was to reach beyond the house meter and place registering apparatus on small and large taps, effectually narrow up the unrecorded wastes and account for all water not actually registered, thus enabling the water department to balance the outgo of water like the wares in any well-regulated business house, where it is realized that care in correcting many small losses, which in the aggregate are excessive, will tend to make the business sure and the profits larger than where no systematic record of profit and loss is kept.

If a leak in a house service or street main is reported it invariably arouses immediate action on the part of the management to correct the defect; if the same management is reasonably certain that hidden wastes occur on fire-service pipes, so called, in mill

yards, into drains, under canals or waterways, in some cases it requires considerable time to get all parties concerned interested and the wastes stopped.

This condition of affairs might have gone on indefinitely but for the agitation which this issue has brought up within a comparatively short time, and which at present is much discussed among the water-works fraternity, underwriters, and fire insurance companies.

The main question appears to be, "Shall all taps and fire-service connections be metered, irrespective of size or condition?"

There seems to be no disposition to object to the placing of meters on domestic, manufacturing or miscellaneous supplies, but when a department proposes to meter a fire service in order to determine whether there are leaks, wastes, or the surreptitious taking of water a protest is generally entered on account of the possibility of such action retarding the flow or entirely shutting off the supply when most needed, and, incidentally, on the part of the water taker, against the cost of such meter.

Lowell is a manufacturing and industrial city, and has at the present time the following number of fire services: 1 1½-inch, 19 2-inch, 48 4-inch, 42 6-inch, 9 8-inch, 2 10-inch, 3 12-inch, a total of 124. Within a few months the water-works department has discontinued 15 12-inch and 2 8-inch fire services. With only one fire service metered (4-inch Crown meter), almost all information is lacking in regard to what water is honestly wasted by curable and incurable leaks, or what is dishonestly taken and used by interests having the special privilege of adequate and copious supplies, in some cases far in excess of other concerns, which in many instances pay as much, if not more, for the maintenance of the water-supply system.

If these particular and amply supplied corporations or individuals with privileged protection are willing to go to considerable expense in complying with underwriters' demands in equipping their plants with outside and inside systems of fire protection, is it too much to have water departments place mechanical watchmen and detectors on the pipe lines and receive compensation for all water used or wasted other than for fire fighting needs? Such a request from a water-works view-point seems reasonable. The

reply from the underwriters to such a request is, generally, "If you place positive meters on fire pipes you jeopardize the risk in case of fire."

If that is so, why not have another service with a meter, or a battery of metered services, so arranged that the meters will record the small flows, and in case of an emergency will supply the required quantity, and by so doing safeguard the interests of all parties concerned? Is it not just that underwriters should eliminate this apprehension and be fair to those who are willing to provide free the means to fight their greatest foe?

The conditions in Lowell, coupled with the present discussion on private fire protection and detection and prevention of water waste, influenced the Lowell water board, after careful consideration, to formulate the following —

REGULATIONS GOVERNING PRIVATE FIRE-SERVICE PIPES.

First. All water for fire-service pipes shall be metered; meter to be furnished and set by city at the owner's expense. No charge shall be made, however, for water used exclusively for the extinguishing of fires.

Second. All main pipes for fire services shall be furnished and connected by the city at the expense of the owner.

Third. Where a standpipe, tank or cistern is used it shall be constructed in such a manner as to shield and protect the water from all possible pollution.

Fourth. Provision shall be made in its construction for means of access to the interior of it by the superintendent or other agents of the water department for the purpose of inspection, and so as to allow for its cleaning as required by the water department.

Fifth. It shall also be fitted with a pipe for the purpose of drawing off all the water at such intervals as required by the water department.

Sixth. Said draw-off pipe must not be connected with a sewer or drain in a way that might lead to the contamination of the water from such source.

Seventh. All expenses not mentioned herein incurred on account of fire services shall be borne by the corporation, firm or individual owning the protected premises.

Eighth. The water board shall have the power from time to time to prescribe whatever other rules they may deem necessary.

The water board, having determined that water for fire-service supplies shall be metered, decided to investigate and find, if possible, the relative merits and comparative worth of different types of large meters or devices, with respect to their local applicability under varying conditions, the sensitiveness, accuracy, and loss of pressure due to the meter, or any other unusual or special characteristics, either favorable or unfavorable, for the uses for which such meters were designed; to determine also their reliability as detectors of small or large wastes, and their capability of passing the maximum quantity of water with the least retardation consistent with the type of meter; to endeavor to find a meter least liable to clog and stop when most needed to perform its work, to obtain a meter or measuring device having the essentials of simplicity, solidity, and durability, a meter that can be easily inspected, cleaned, and repaired; in short, to obtain the information necessary to guide the department in selecting the meters or devices suited to the particular work required.

The available data was not sufficient to instruct the water board or property owners in adopting any particular type of meter or device, as it is only quite recently, probably on account of the discussion among water-works people for large-sized meters, that some of the meter companies have been aroused to an increased activity and consequent keener competition in the manufacture and sale of large meters.

The testing of small or house meters by water departments has long been a custom, and the importance and necessity of such testing should make it as unlimited in its scope as is the law of having a sealer of weights and measures in every city and town to examine and stamp his seal of approval on every scale and measure, large or small, within his jurisdiction.

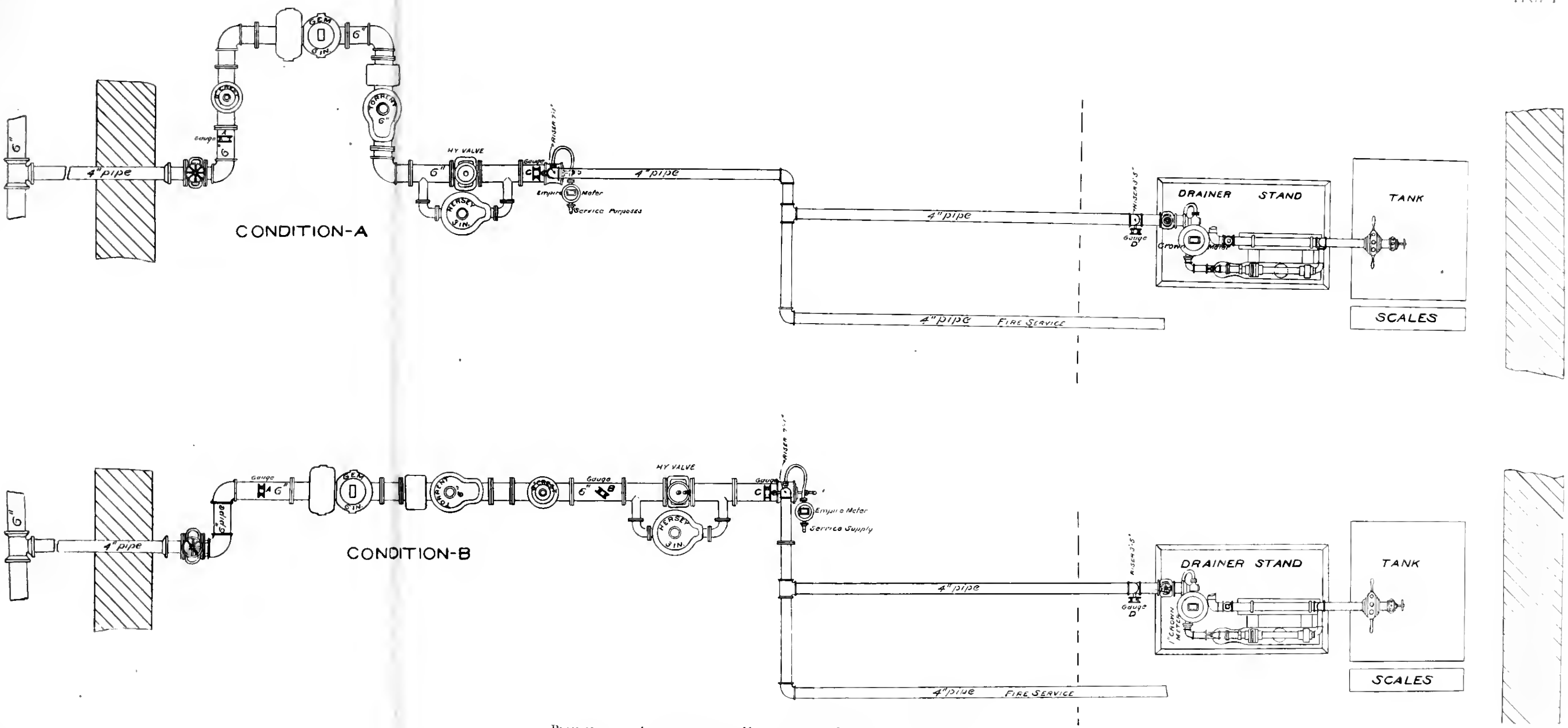
Then why do water departments and meter manufacturers limit testing to small meters, and test large meters on small flows only? Is it not of equally great importance where large meters are needed and used that something should be known of their performance and correctness, and that they should not be purchased, accepted, and installed on mere recommendation of a meter manufacturer, who will tell you, in most cases, that the large meters have been tested on small flows, and the meter is

supposed to be correct for larger flows because it is a larger pattern of the smaller models?

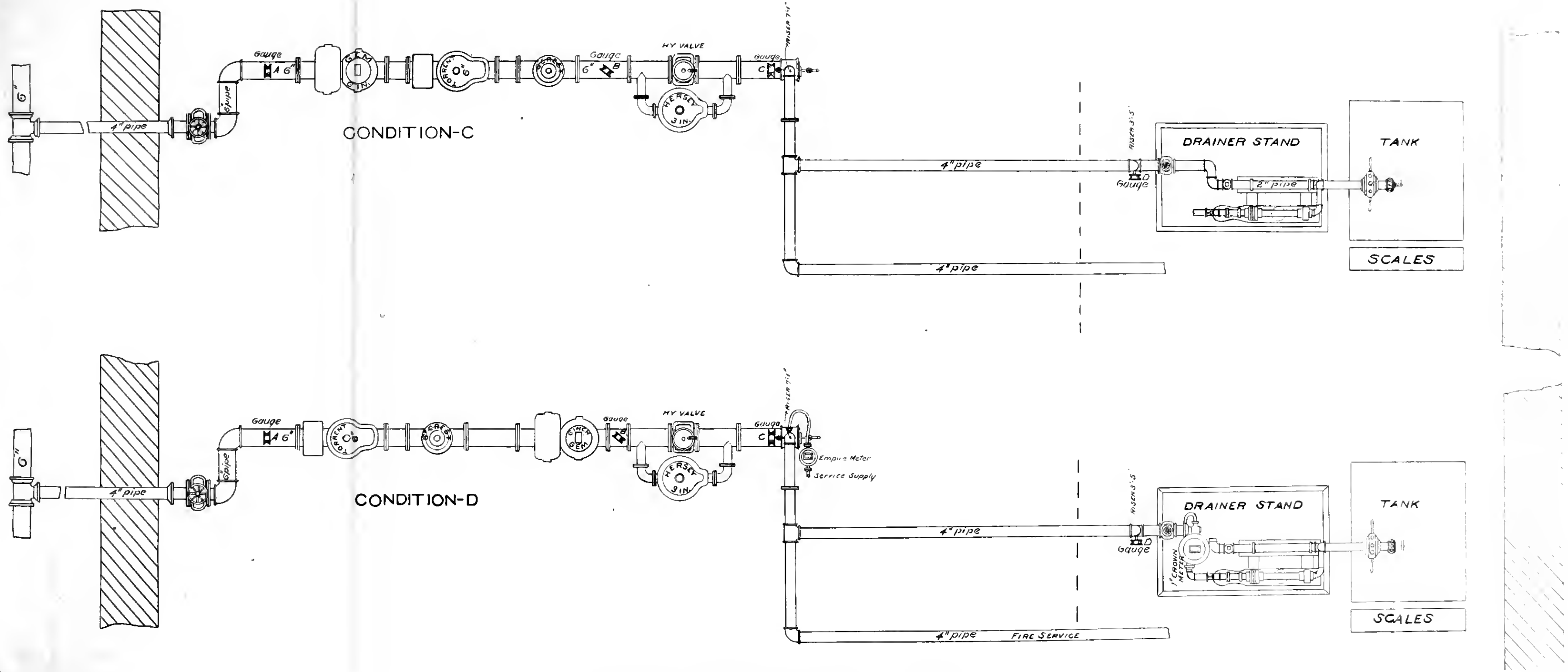
Having decided to get at the facts, our superintendent, Mr. R. J. Thomas, invited the manufacturers to submit different types of meters and devices to be tested, to enable us to observe their action. After the meters were delivered, the query was, how to obtain the desired information. Lowell, like similar water departments, had apparatus and facilities for testing small meters, and large meters on small flows. Not having better facilities at hand, and fully understanding that such tests would be incomplete and inconclusive, we decided, for a more complete test with the facilities at hand, to vary the usual test of separate meters by connecting them in series, and getting the comparative results.

The meters were set on the basement floor and near the small testing rig. The water for the tests was supplied through a 4-inch pipe used for fire service and testing purposes, and fed by a 6-inch street main, about 25 feet from the building, the street main in turn being supplied from a 12-inch distribution pipe direct from the low-service reservoir, ensuring a constant and steady supply.

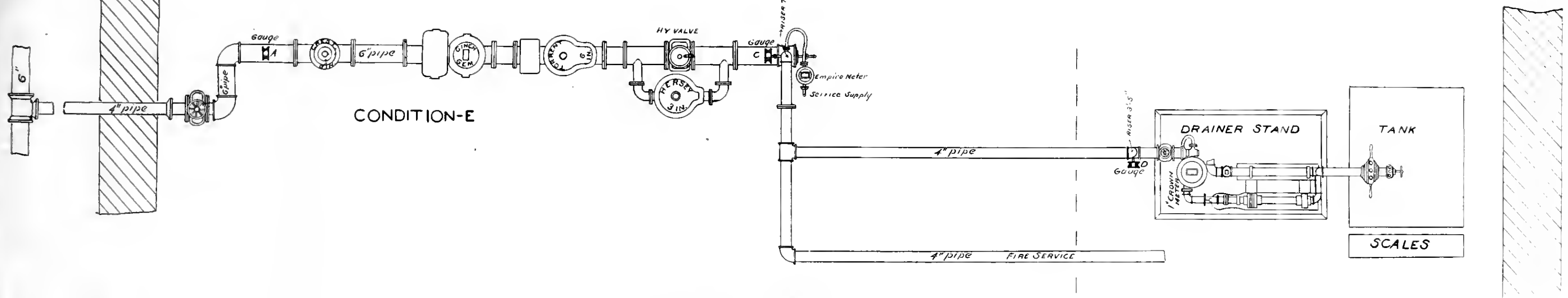
The first arrangement, or condition A (as shown, Plate I), was made up of three current meters, a 6-inch Crest, 6-inch Gem and 6-inch Torrent, forming the letter U. On the outlet side was placed a 6-inch Tilden's device with 3-inch Hersey disc meter on by-pass; from the outlet end of this device a 4-inch riser was run to the testing apparatus for small meters. On this riser was tapped a connection for supplying the shop through a $\frac{3}{4}$-inch Empire meter with water for ordinary purposes, such as the intermittent use of water for two sinks, two water-closets, and one washstand. During the time the shop was getting its supply from this source the regular service supply was cut off, and the water used for testing small meters at the weighing tank was checked and recorded by a 1-inch Crown meter. As the test proceeded it was found that the 3-inch Hersey disc was a close registering meter and agreed with the amount of water recorded by both the $\frac{3}{4}$-inch Empire and 1-inch Crown. While testing the current meters for sensitiveness and accuracy on different sized streams through the multiple



Plan showing Arrangements of Meters during Comparative Tests of 1904.

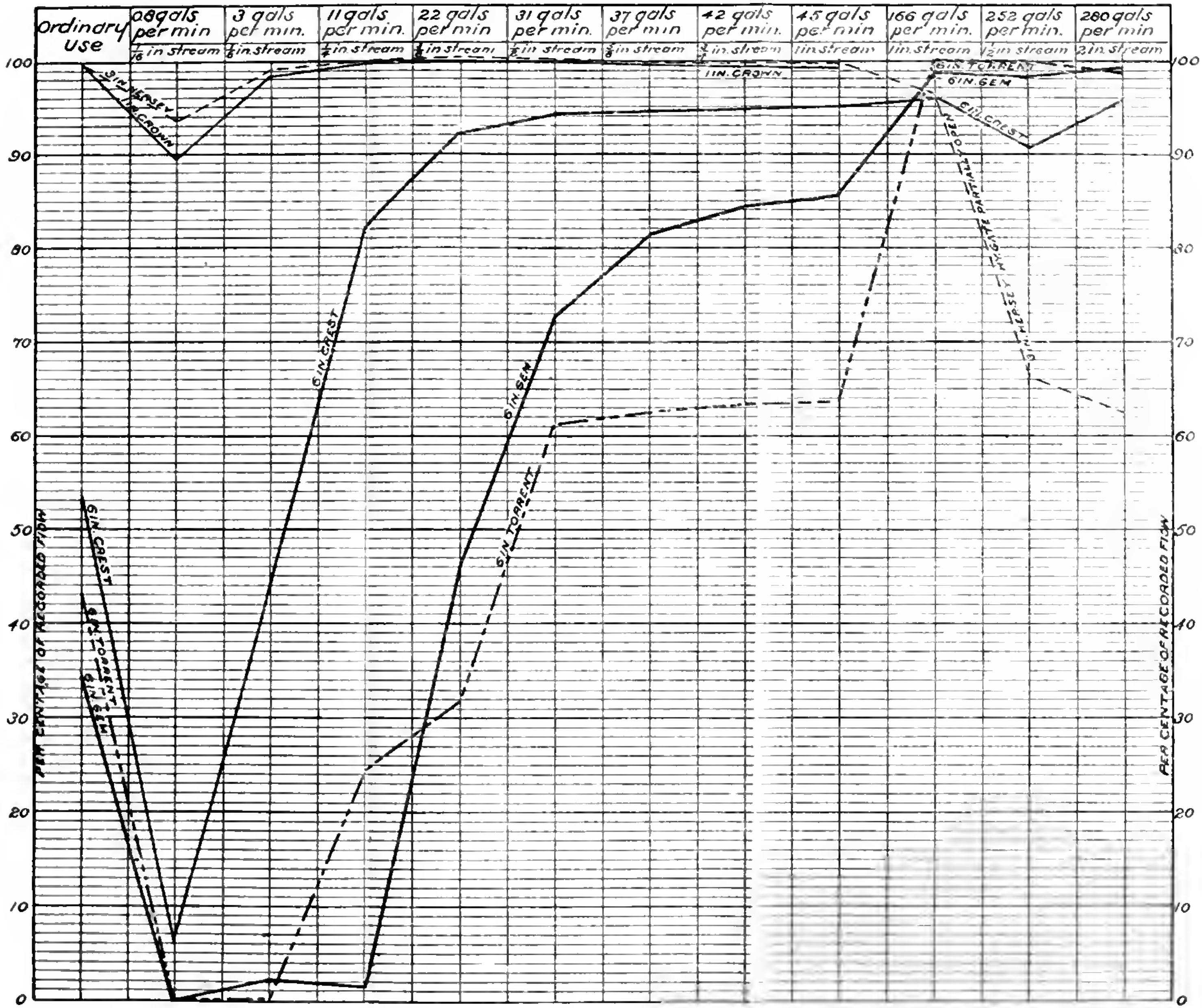


PLAN SHOWING ARRANGEMENTS OF METERS DURING COMPARATIVE TESTS OF 1901



Plan showing Arrangement of Meters during Comparative Tests of 1904.

DIAGRAM OF RECORDED FLOW



›el ›nd weighing the discharge in the tank, the shop was supplied , its own service.

Under the "ordinary-use" test, we undertook to find which tl current meters would show the largest percentage of ›gist›ation under conditions similar to those met with in practice where water is used, or wasted through carelessness or otherwise.

On testing for sensitiveness on 1–16-inch to ½-inch streams, requiring considerable time for the registering hands to make complete revolutions on the dial, so as to eliminate any error due ›› the adjustment of the index hands, the apparatus could be set operation and allowed to run unattended for hours or days, and careful timing, gaging of discharges before and after each est, and also comparing the check meters, very accurate results ›e obtained.

Before beginning the series test the meters were thoroughly flushed through a 2-inch opening; the first meter on the line failed to register; an inspection showed that several ounces of soft, slimy sediment had accumulated on the working parts of the meter, but this was considered insufficient to derange in any way the proper working of this type of meter. Shortly before the meters were flushed a half-inch hole was drilled and tapped on ›let side of meter to connect pressure gage, care being used that ›ne of the drillings should get into the meter. None were found at the time the meter was opened and examined. This failure to record brought up the question, — Did position in the arrangement or line have any effect on registration? Some meter men, owing to a lack of better information, were inclined to believe it to be so.

To satisfy some of the meter men and gather information on this point, a new arrangement and alignment of the meters was made, the meters being made interchangeable by fitting with nipples and uniform flanges. The meters were then successively tested under conditions B, C, D, E. (See Plates I, II, III.)

During a portion of the test under condition E, it was found that small rates of flow through one of the current meters did not cause any movement of the register until the 1-inch stream with sufficient water pressure to overcome the adhesion set it in motion.

We tried repeatedly afterwards to obtain like results on small streams, but on each occasion the meter registered.

After obtaining considerable practical information with the facilities limited to a 2-inch opening on the multiple cock, inadequate drainage for larger flows and a small weighing tank, we fully realized that to make more complete tests some other arrangement would be necessary.

Plates I, II, and III show the different arrangements of meters during the series tests.

On Plate IV is graphically shown the average recorded flow of the meters under different conditions and different rates of discharge.

On Plates V, VI, and VII are shown in tabulated form the results of the comparative tests of meters connected in series.

In studying the best methods of measuring the flow of water and checking the registration of meters, the nozzle seemed to be best adapted for such work and could readily be employed as a practical check meter; we felt fully convinced that Mr. John R. Freeman's experiments with nozzles were conclusive. As Mr. Freeman says, "The nozzle will, I think, on reflection, be granted to be the most portable and compact gaging apparatus in proportion to its capacity which has ever been devised for such purposes."

To give further confidence in the use of the nozzles, Mr. Freeman asked himself the question, "Is any accidental variation in method of setting up liable to introduce a change of rate or error in its indication while using the coefficient as previously determined once for all?" In answer to his own question, he says, "In the subsequent use of this particular piece of apparatus, we may (if our pressure gage is all right and the apparatus set up in almost any reasonable manner) have the greatest confidence that the error of any series of measurements would not exceed one half of one per cent."

The expense of such installation is not prohibitive; quoting Mr. Frank C. Kimball, "As the expense of installing a permanent testing plant for large meters is not great, comparatively speaking, by the installation of such testing plants in several of the larger cities there would result, in our opinion, a toning up, as it were, of

COMPARATIVE TEST OF METERS CONNECTED IN SERIES.

CONDITION-A

Size of Meters	Meters	Ordinary Use: Recorded Flow By Weight cu. ft.	Recorded Flow By Meter cu. ft.	Unrecorded Flow Cubic Feet	Unrecorded Flow Per Cent	Discharge gals. per min.
¾"	Empire }	13471	13471	0.0	0.0	
1"	Crown }					
3"	Hersey	13471	13390	81.0	0.6	
6"	Crest	13471	456	13015	96.61	
6"	Torrent	13471	12595	876	6.50	
6"	Gem	13471	11900	1571	11.66	

Note: The meters were arranged as per Condition A. (See Sketch). After thoroughly flushing meters with large streams, began test on small flows; found that Crest meter failed to register. Notified the makers; their agent inspected the meter and failed, according to his statement, to find sufficient cause for the stoppage. Several ounces of soft slimy sediment had accumulated on the working parts of the meter, but was considered by those conducting the test as insufficient to derange, in any way, the proper working of a meter. Before the stoppage a half inch hole had been drilled and tapped on pipe line to connect a pressure gauge, care being taken that none of the drillings should get into the pipe; none were found at the time the meter was opened and examined.
The question whether the sediment, drillings, or other obstruction caused the stoppage remains unanswered.
The following tables show the registration and performance since the examination and cleaning of the Crest meter.

CONDITION-B

Kout [illegible]

Size of Meters	Meters	$\frac{1}{16}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic feet	Per Cent	Discharge gals. per min.	$\frac{1}{8}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic feet	Per Cent	Discharge gals. per min.	$\frac{1}{4}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per Cent	Discharge gals. per min.
½"	Empire															
1"	Crown	249.9	238	11.9	40	80	964.5	939	25.5	2.6	2.96	1380	1380	0.0	0.0	10.71
3"	Hersey	2499	238	11.9	4.0	80	964.5	952	12.5	1.3	2.96	1380	1374	6.0	0.43	10.71
6"	Crest	2499	9	240.9	96.4	80	964.5	306	658.5	68.3	2.96	1380	1155	225	16.3	10.71
6"	Torrent	2499	0	249.9	100.	.80	964.5	15	949.5	98.4	2.96	1380	1026	354	25.60	10.71
6"	Gem	2499	0	249.9	100.	80	964.5	29.5	935.	96.9	2.96	1380	43	1337	96.9	10.71

Size of Meters	Meters	$\frac{3}{8}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per cent	Discharge gals. per min.	$\frac{1}{2}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per cent	Discharge gals. per min.	$\frac{5}{8}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per cent	Discharge gals. per min.
½"	Empire															
1"	Crown	2892	2892	0.0	0.0	23.69	3882	3875	7.0	0.18	30.66	[illegible]	4740	26	0.54	37.71
3"	Hersey	2892	2902	*10.0	*0.34	23.69	3882	3887	*5.0	*0.13	30.66	[illegible]	4758	8	0.17	37.71
6"	Crest	2892	2686	206	7.12	23.69	3882	[illegible]	231	5.95	30.66	[illegible]	4499	267	5.60	37.71
6"	Torrent	2892	2687	205	7.06	23.69	3882	3692	190	4.89	30.65	[illegible]	4606	158	3.31	37.71
6"	Gem	2892	1615	1277	[illegible]	23.69	3882	[illegible]	1103	28.41	30.66	[illegible]	3862	904	18.96	37.71

Size of Meters	Meters	$\frac{3}{4}$ inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per cent	Discharge gals. per min.	1 inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per Cent	Discharge gals. per min.
½"	Empire										
1"	Crown	750	745	5.0	0.66	42.74	1535	[illegible]	9.0	0.58	45.31
3"	Hersey	750	747	[illegible]	0.40	42.74	1535	1534	1.0	0.06	45.31
6"	Crest	750	[illegible]	[illegible]	[illegible]	42.74	1535	1455	80.0	5.21	45.31
6"	Torrent	[illegible]	[illegible]	[illegible]	[illegible]	42.74	1535	1499	36.0	2.34	45.31
6"	Gem	750	621	29	[illegible]	42.74	1535	1287	248	16.16	45.31

Size of Meters	Meters	[illegible] inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per cent	Discharge gals. per min.	[illegible] inch opening: Recorded Flow By Weight cu. ft.	By Meter cu. ft.	Unrecorded Flow Cubic Feet	Per cent	Discharge gals. per min.	Remarks
½"	Empire											[illegible]
1"	Crown											Rotary Piston M[illegible]
3"	Hersey	103	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Disc Meter
6"	Crest	103	[illegible]	[illegible]	[illegible]	67.38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Current Meter
6"	Torrent	103	[illegible]	[illegible]	1.34	67.38	[illegible]	76½	*2.5	*3.37	25.62	Current Meter
6"	Gem	03	103	0	0	67.38	74	73½	0.5	0.67	25.62	Current Meter

*over-registration

Note: [illegible] Hy Gate on Tilden's entrance slightly [illegible]

Note: 6" Hy Gate on Tilden's entrance opened [illegible] inch. Loss of head [illegible]

CONDITION-D

Size of Meters	Meters	1/16 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1/8 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1/4 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min
3/4"	Empire															
1"	Crown	97	85	12	12.37	.80	384	376	8.0	2.08	3.06	1435	1434	1.0	0.07	11.29
3"	Hersey	97	91	6	6.18	.80	384	384	6.0	1.56	[illegible]	1435	1435	0.0	0.0	11.29
6"	Crest	97	8	89	91.75	.80	384	164	120	31.25	3.06	1435	1183	252	17.56	11.29
6"	Torrent	97	00	97	100	.80	384	2	382	99.47	3.06	1435	4	1431	99.72	11.29
6"	Gem	97	00	97	100	.80	384	12	372	96.87	3.06	1435	12	1423	99.16	11.29

Size of Meters	Meters	3/8 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1/2 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	5/8 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min
3/4"	Empire															
1"	Crown	[illegible]	2678	0.0	0.0	21.55	3908	3908	0.0	0.0	31.41	[illegible]	619	2.5	0.40	36.85
3"	Hersey	[illegible]	2698	*20.	*0.74	21.55	3906	3924	*16.	*0.4	31.41	[illegible]	622	*0.5	*0.08	36.85
6"	Crest	2678	2378	300	11.20	21.55	3906	3684	224	5.73	31.41	621.5	588	33.5	5.39	36.85
6"	Torrent	2678	25	2653	99.06	21.55	3906	3455	453	11.59	31.41	621.5	567	54.5	8.76	36.85
6"	Gem	2676	1009	1669	62.32	21.55	3906	2867	1041	26.63	31.41	621.5	[illegible]	106.5	17.13	36.85

Size of Meters	Meters	3/4 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	By Weight cu ft	By Meter cu ft	Cubic Feet
3/4"	Empire													
1"	Crown	654	[illegible]	4.0	0.6	42.31	[illegible]	[illegible]	3.0	0.96	44.5			
3"	Hersey	654	654	0.0	0.0	42.31	311	[illegible]	[illegible]	0.32	44.1	87	[illegible]	2.0
6"	Crest	654	621	33.	5.04	42.31	311	[illegible]	16.0	5.14	44.5	[illegible]	[illegible]	[illegible]
6"	Torrent	654	607	47.	7.18	42.31	311	291	20.0	6.43	[illegible]	[illegible]	[illegible]	10
6"	Gem	654	560	94	14.37	42.31	311	270	41.0	[illegible]	[illegible]	57	66	10

*Over-registration

Same as Condition C

Note: [illegible] Tilden's [illegible] slightly [illegible] opened [illegible] 1/8 inch [illegible] Loss of pressure [illegible]

Remarks:
[illegible] Piston Meter
Rotary Piston Meter
Disc Meter
Current Meter
Current Meter
Current Meter

CONDITION-E

Size of Meters	Meters	1/16 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1/8 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1/4 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min
3/4"	Empire															
1"	Crown	101	87	14	13.86	.80	394	392	2	0.50	3.07	1409	1409	0.0	0.0	11.25
3"	Hersey	101	93	8	7.92	.80	394	395	*1	*0.25	3.07	1409	1411	*2.0	*0.14	11.25
6"	Crest	101	7	94	93.06	.80	394	135	259	65.73	3.07	1409	1143	266	18.80	11.25
6"	Torrent	101	0	101	100	.80	394	0	394	100.	3.07	1409	0	1409	100	11.25
6"	Gem	101	0	101	100	.80	394	6	388	98.47	3.07	1409	20	1389	98.58	11.25

Size of Meters	Meters	3/8 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1/2 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	5/8 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min
3/4"	Empire															
1"	Crown	2720	2720	[illegible]	0.0	21.47	3887	3881	6.0	0.15	31.31	653	650	3	.46	36.77
3"	Hersey	2720	2735	*15	*.55	21.47	3887	3884	3.0	0.06	31.31	653	652	1	0.15	36.77
6"	Crest	2720	2581	139	5.11	21.47	3887	3682	205	5.27	31.31	653	620	33	5.05	36.77
6"	Torrent	2720	55	2665	97.97	21.47	3887	0	3887	100	31.31	653	0	653	100	36.77
6"	Gem	2720	1250	1470	54.04	21.47	3887	2876	1011	26	31.31	653	527	126	19.29	36.77

Size of Meters	Meters	3/4 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1 inch opening: Recorded Flow By Weight cu ft	By Meter cu ft	Unrecorded Flow Cubic Feet	Per Cent	Discharge gal per min	1 inch opening: By Weight cu ft	By Meter cu ft	Cubic Feet
3/4"	Empire													
1"	Crown	935	930	5	0.53	41.78	626	626	2	0.31	43.93			
3"	Hersey	935	933	2	0.21	41.78	626	626	2	0.31	43.93	76	73	3
6"	Crest	935	889	46	4.92	41.78	628	599	29	4.61	43.93	76	71	5
6"	Torrent	935	0	935	100	41.78	628	0	628	100	43.93	76	76	0
6"	Gem	935	797	138	14.75	41.78	628	543	85	13.53	43.93	76	74	2

*Over-registration

Note: Torrent Meter stopped

Test same as Condition C

Note: Torrent started [illegible] 6" Hy. Gate [illegible] Tilden's contrivance slightly jarred and opened.

Note: Only Gate on Tilden's contrivance opened 1/2 inch Loss, pressure 11 lbs

Note: Only Gate on Tilden's contrivance opened 3/4 inch Loss of pressure 12 lbs.

Remarks:
[illegible] Piston Meter
Rotary Piston Meter
Disc Meter
Current Meter
Current Meter
Current Meter

NOTE.—During a part of the test under Condition E [illegible] sketch, the 6-inch Torrent meter was blocked [illegible] sediment that pocketed in a depression of the deflector where the bottom of bushing rests on the spindle. After completion of the test a representative of the Hersey Manufacturing Company cleaned and smoothed bushing and spindle. At a subsequent test the meter showed about the same percentage of registration as before the stoppage.

At the conclusion of the test the 6-inch Gem meter was examined and cleaned by an inspector from the National Meter Company. He considered the meter in good condition, except "that the rubber bushing had expanded somewhat closer to the bearing [illegible] the meter was adjusted at the factory, due to the difference of temperature." He smoothed the spindle and slightly reduced the bushing. The meter recorded about the same amount of flow as before the inspection.

TABLE SHOWING PER CENT OF UNRECORDED FLOW OF DIFFERENT WATER METERS.

Size of Meters	Meters	$\frac{1}{16}$ inch opening, Condition B	C	D	E	Average	$\frac{1}{8}$ inch opening, Condition B	C	D	E	Average	$\frac{1}{4}$ inch opening, Condition B	C	D	E	Average
$\frac{3}{4}$"	Empire															
1"	Crown	48		12.87	13.66	10.34	2.6		2.08	0.50	1.73	0.0		0.07	0.0	0.2
3"	Hersey	4.6		6.18	7.92	6.30	1.3		1.56	*0.25	0.87	0.43		0.0	*0.14	0.09
6"	Crest	96.4		91.75	93.06	93.73	56.3		31.25	65.73	55.09	16.3		17.56	18.80	17.55
6"	Torrent	100		100	100	100.	98.4		99.47	100	99.29	25.66		99.72	100	75.13
6"	Gem	100		100	100.	100.	96.9		96.67	98.47	97.41	96.9		99.16	98.58	98.21

Size of Meters	Meters	$\frac{3}{8}$ inch opening, Condition B	C	D	E	Average	$\frac{1}{2}$ inch opening, Condition B	C	D	E	Average	$\frac{5}{8}$ inch opening, Condition B	C	D	E	Average	$\frac{3}{4}$ inch opening, Condition B	C	D	E	Average
$\frac{3}{4}$"	Empire																				
1"	Crown	0.0		0.0	0.0	0.0	0.16		0.0	0.15	0.11	0.34		0.40	0.46	0.46	0.66		0.6	0.53	0.59
3"	Hersey	*0.34		*0.74	*0.55	*0.54	*0.13		*0.4	0.06	*0.16	0.17		*0.08	0.15	0.08	0.40		0.0	0.21	0.20
6"	Crest	7.12		11.20	5.11	7.81	5.95		5.73	5.27	5.65	5.60		5.39	5.05	5.34	5.33		5.04	4.92	5.09
6"	Torrent	7.08		99.06	97.97	68.03	4.89		41.59	100	38.82	3.31		8.76	100	37.35	2.80		7.18	100.	36.66
6"	Gem	44.15		62.32	54.04	53.50	28.41		26.63	26.0	27.01	18.96		17.13	19.29	18.46	17.20		14.37	14.75	15.44

Size of Meters	Meters	1 inch opening, Condition B	C	D	E	Average	1 inch opening, Condition B	C	D	E	Average	$1\frac{1}{2}$ inch opening, Condition B	C	D	E	Average
$\frac{3}{4}$"	Empire															
1"	Crown	0.58		0.96	0.31	0.61										
3"	Hersey	0.06		0.32	0.31	0.23		2.91	2.29	3.94	3.04		32.43	37.01	31.94	33.79
6"	Crest	5.21		5.14	4.61	4.98		2.91	2.29	6.58	3.92		8.78	11.69	6.94	9.13
6"	Torrent	2.34		6.43	100	36.25		*1.94	1.14	0.0	*0.26		*3.37	0.0	2.77	*0.20
6"	Gem	16.16		13.15	13.53	14.28		0.0	1.14	2.63	1.25		0.67	6.5	*1.39	1.92

Size of Meters	Meters	2 inch opening, Condition B	C	D	E	Average	Ordinary use, Condition A	B	D	E	Average	General Average of unrecorded flow	Competitive Position
$\frac{3}{4}$"	Empire												
1"	Crown						0.0	0.0 0.0	0.00	0.0	0.2	1.57%	Second
3"	Hersey			38.35	36.46	37.41	0.0	0.0 0.1	0.2	0.79	0.33	1.12% 6.80% gate partially open	First
6"	Crest			4.10	4.05	4.08	96.61	[illegible]	33.63	42.98	45.75	21.51%	Third
6"	Torrent			4.10	*1.33	.38	6.50	81.50 81.7	85.97	83.07	56.01	45.70% [illegible]	Fifth
6"	Gem			1.37	0.0	0.68	11.66	45.76 93.93	86.87	79.29	64.70	41.07%	Fourth

*over-registration

SUMMARY

Discharge	First	Second	Third	Fourth	Fifth
$\frac{1}{16}$ in stream	Hersey	Crown	Crest	Torrent	Gem
$\frac{1}{8}$ " "	Hersey	Crown	Crest	Gem	Torrent
$\frac{1}{4}$ " "	Hersey	Crown	Crest	Torrent	Gem
$\frac{3}{8}$ " "	Crown	Hersey	Crest	Gem	Torrent
$\frac{1}{2}$ " "	Crown	Hersey	Crest	Gem	Torrent
$\frac{5}{8}$ " "	Hersey	Crown	Crest	Gem	Torrent
$\frac{3}{4}$ " "	Hersey	Crown	Crest	Gem	Torrent
1 " "	Hersey	Crown	Crest	Gem	Torrent
1 " "	Torrent	Gem	Hersey	Crest	
$1\frac{1}{2}$ " "	Torrent	Gem	Crest		
2 " "	Gem	Torrent	Crest		
Ordinary Use	Crown	Hersey	Crest	Torrent	Gem

Note: Ordinary use, the intermittent use of water for two sinks, two water closets, one wash stand and testing tank.

the meter manufacturers to a more thorough consideration of the requirements of both water departments and insurance underwriters."

To successfully establish a large meter-testing plant, the necessary requisites are, first, an abundant water supply; second, readiness for rapid drainage; third, suitable apparatus.

On the department's premises at Lowell we found two places combining the first two requisites; the first location considered was at Station 2, where the apparatus could be erected in the open, similar to the one installed by Mr. Kimball at Knoxville, Tenn., which gave such excellent results. At Lowell this arrangement would have the disadvantage of being serviceable during the warm weather only, and another objection was that this station is a reserve plant and consequently the apparatus would have to be housed after each series of tests; and further, notwithstanding that water is cheap to the department, if a willful waste can be avoided it is in line of economy. The second place, and the one selected, was in the engine-room of Station 1, it having, in our opinion, all the requisites, with the additional advantages of being ready for use at any or all times, economy of water, compactness, light, heat, pleasant and convenient surroundings, and proximity to water-works repair shop. The engine-room being large and roomy, we selected the westerly side and installed what is probably the first permanent testing plant, of its kind, for large meters.

This station is located about one-half mile from the low-service reservoir, with a capacity of 30 000 000 gallons, supplying the city proper through a 30-inch delivery pipe; branching from this pipe, near the reservoir, a 12-inch distribution-pipe line runs directly down hill and into the basement of the pumping-station, there being reduced to an 8-inch pipe, supplying the high-service pump; an 8-inch branch was cut into this line and the pipe laid under the basement floor to the westerly wall of the station; an 8-inch elbow with riser extended to 25 inches above engine-room floor; another 8-inch elbow reducing to 6-inch pipe with a 6-inch gate valve controlling the inlet; from this valve about 8 feet of 6-inch wrought-iron pipe to inlet piezometer; next a space for the insertion of any size meter or device from 3 inches to 12 inches, the meters being swung into position by means of a hoisting rigging; on the

outlet flange of the meter another piezometer ring was attached, then about 8 feet more of wrought-iron pipe to pressure piezometer and nozzles; between the nozzles and meter a 6-inch valve was sometimes inserted to keep the apparatus from draining and at the same time obtain conditions similar to what is often found in actual use; the nozzles discharged through a sheet-iron spatter box, seven and one-half feet long, into and against a 24-inch cast-iron deflector elbow set directly over the pump well; this deflector complies with the second requisite for testing, readiness for rapid drainage, without discharging or wasting into the open. See Plates VIII and XI.

The whole apparatus is held up in position with adjustable braced wooden chairs, with iron clamps holding the pipes firmly in position without undue vibration. Under the whole string of pipe and apparatus is placed a drainer pan to catch the condensation, drippings or bleeding of the line, all of which wastes into a sewer drain.

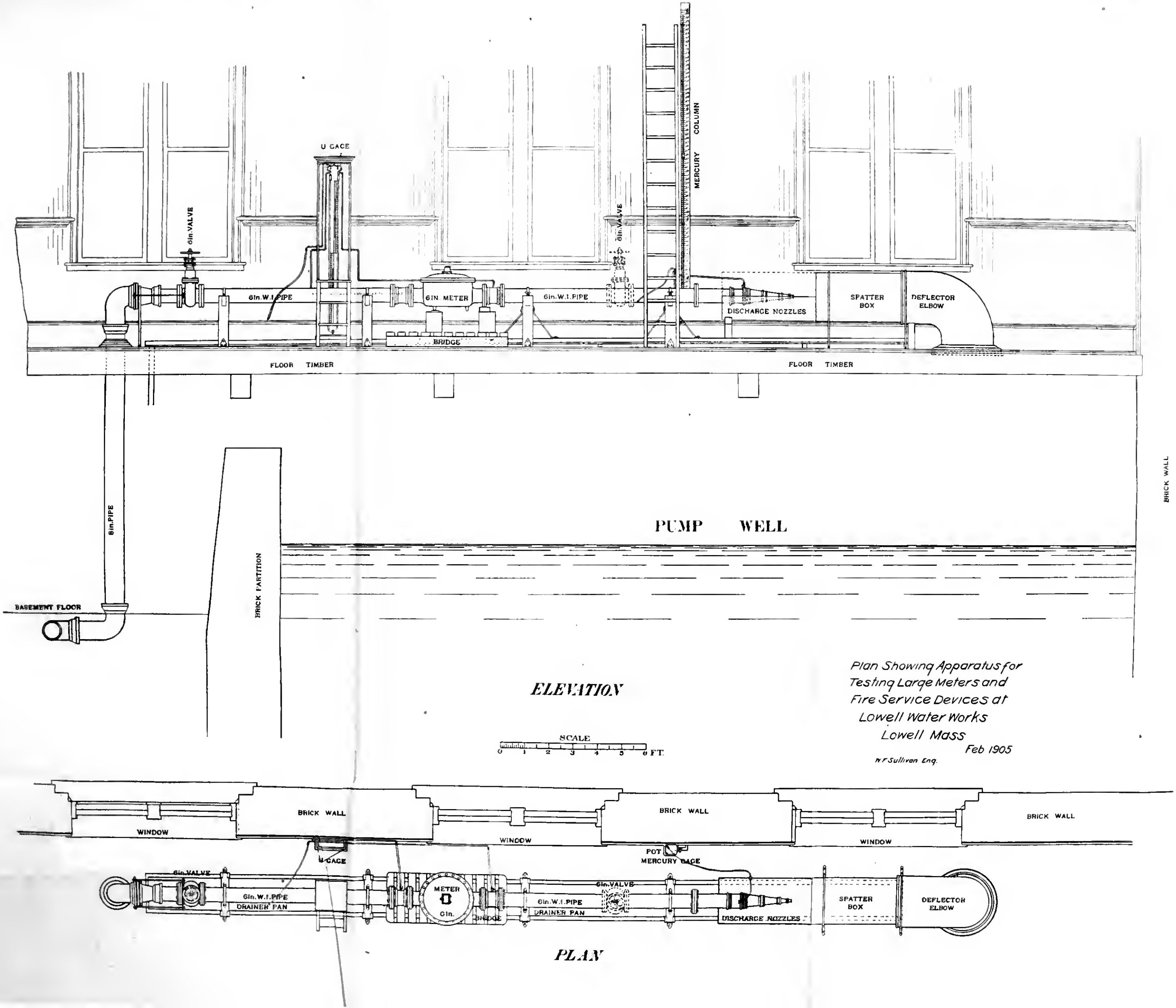
To obtain nozzle discharges, the methods used were substantially those given by Mr. John R. Freeman in his paper on "Hydraulics of Fire Streams," published in Vol. XXI of "Transactions of the American Society of Civil Engineers," and those in his paper on "The Nozzle as an Accurate Water Meter," in "Transactions of the American Society of Civil Engineers," Vol. XXIV, and from methods described by Mr. Frank C. Kimball in his paper before this Association, September, 1903, entitled, "Some Six-Inch Meter Tests and How They were Made." *

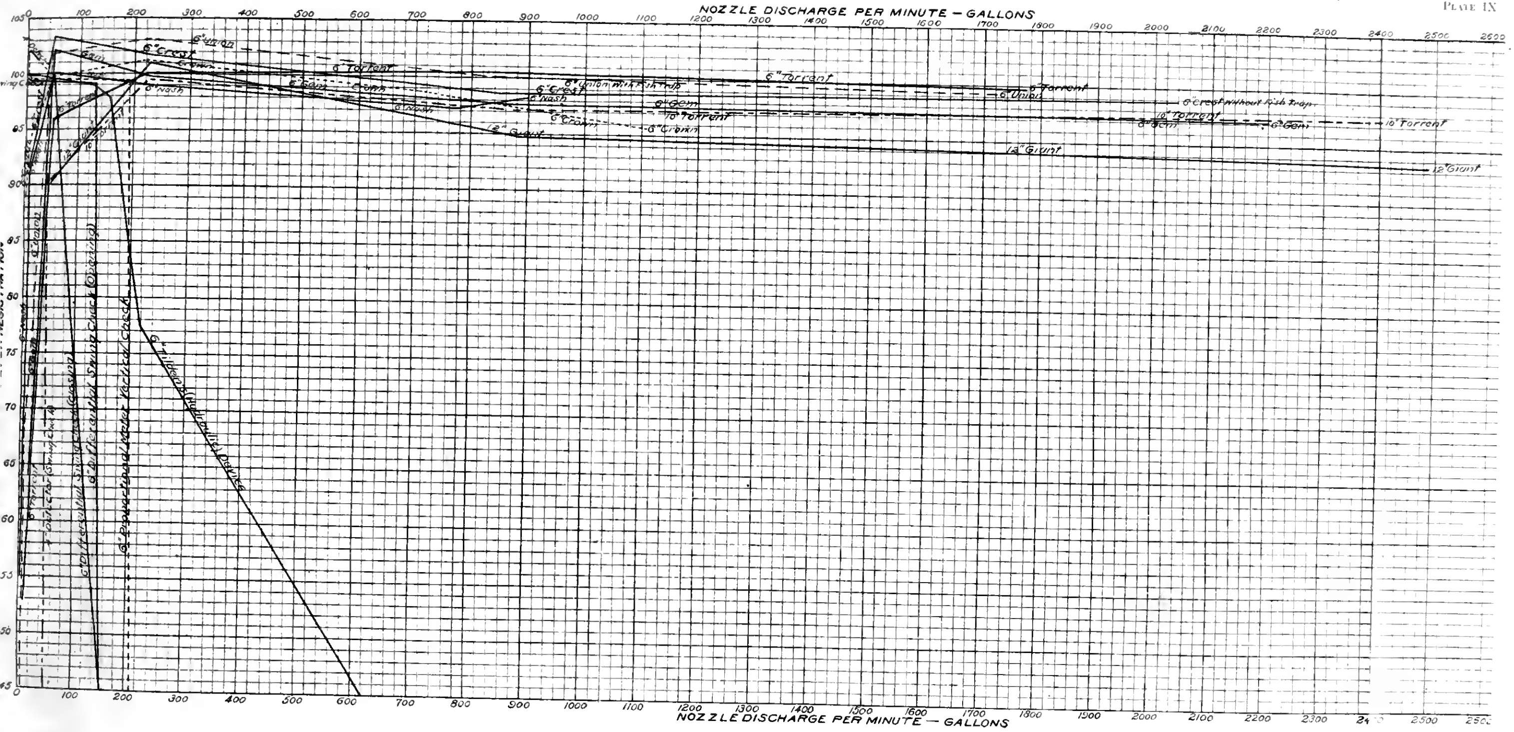
The nozzles used ranged in size of orifice from $\frac{1}{8}$ inch to 4 inches and were made by the Hersey Manufacturing Company, and constructed in accordance with the requirements from experiments by Mr. Freeman.

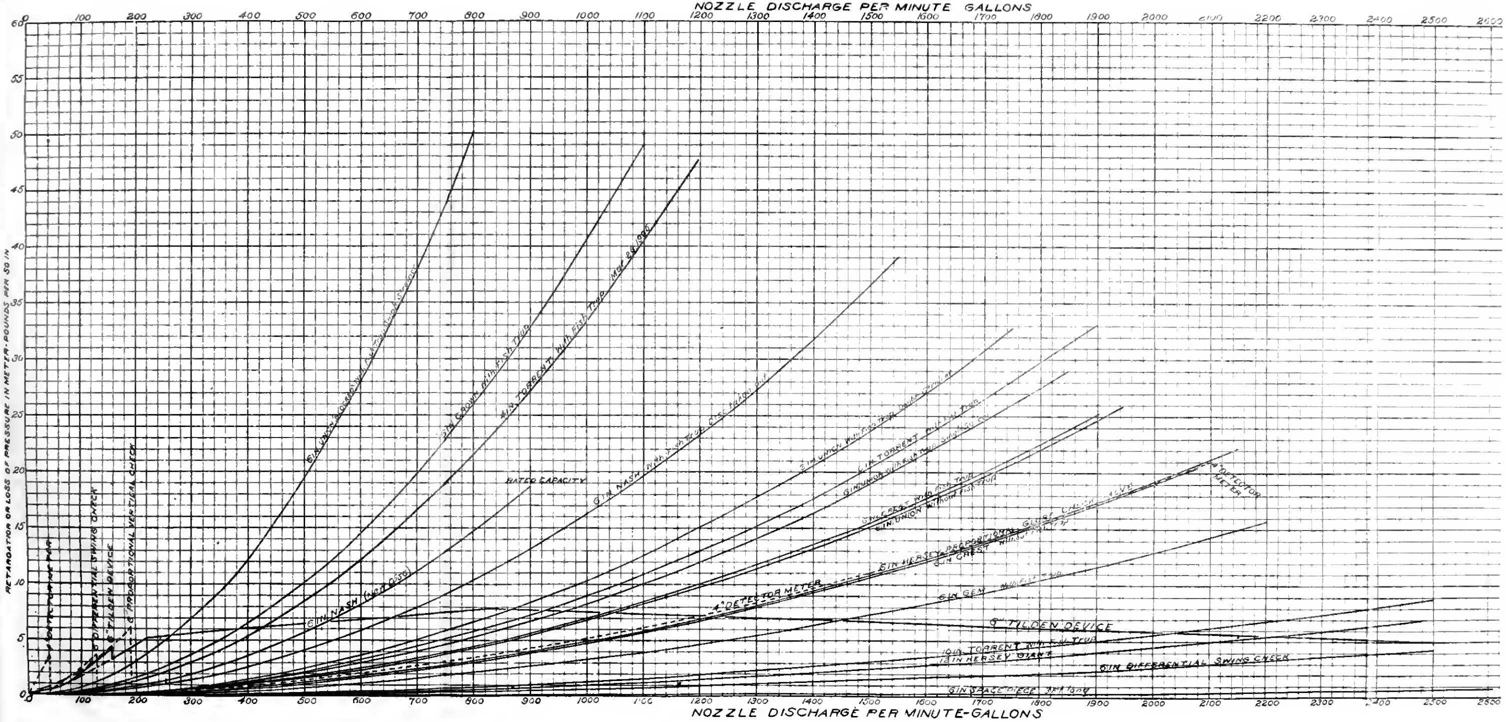
The tests for small flows, that is, 1–16-inch, $\frac{1}{8}$-inch and $\frac{1}{4}$-inch streams, were determined by attaching a 2-inch gate valve on end of 2-inch nozzle and screwing on outlet side a brass cap with circular brass disk, having a "standard circular orifice with sharp edges"; the coefficients for these discharges were determined by experiment.

The water pressure was measured by means of an open mercury column with graduated scale reading to a tenth of a pound. The

* JOURNAL, N. E. W. W. Ass'n., December, 1903, Vol. 17, p. 305.


U GAGE
6in. VALVE
6in. VALVE
MERCURY COLUMN
6in. W.I. PIPE
6IN. METER
6in. W.I. PIPE
DISCHARGE NOZZLES
SPATTER BOX
DEFLECTOR ELBOW
BRIDGE
FLOOR TIMBER
FLOOR TIMBER
6in. PIPE
BRICK PARTITION
PUMP WELL
BRICK WALL
BASEMENT FLOOR
ELEVATION
SCALE
0 1 2 3 4 5 6 FT.
Plan Showing Apparatus for Testing Large Meters and Fire Service Devices at Lowell Water Works Lowell Mass
Feb 1905
H F Sullivan Eng.
WINDOW
BRICK WALL
WINDOW
BRICK WALL
WINDOW
BRICK WALL
U GAGE
POT
MERCURY GAGE
6in. VALVE
6in. W.I. PIPE
DRAINER PAN
METER
6in.
BRIDGE
6in. VALVE
6in. W.I. PIPE
DRAINER PAN
DISCHARGE NOZZLES
SPATTER BOX
DEFLECTOR ELBOW
PLAN


NOZZLE DISCHARGE PER MINUTE — GALLONS
6" Union
6" Crest
6" Torrent
6" Union with Fish Trap
6" Gem
6" Nash
6" Crown
6" Union
6" Crest without Fish Trap
10" Torrent
12" Giant
6" Tilden's (Hydraulic) Device
6" Proportional Meter Vertical Check
6" Differential Swing Check (Opening)
6" Differential Swing Check (Closing)
6" Union
NOZZLE DISCHARGE PER MINUTE — GALLONS



NOZZLE DISCHARGE PER MINUTE GALLONS
RETARDATION OR LOSS OF PRESSURE IN METER-POUNDS PER SQ IN
RATED CAPACITY
6 IN NASH (NEW DISC)
4" DETECTOR METER
6" TILDEN DEVICE
6 IN GEM
6 IN DIFFERENTIAL SWING CHECK
13 IN HERSEY GIANT
6 IN SPACE PIECE
6" PROPORTIONAL VERTICAL CHECK
NOZZLE DISCHARGE PER MINUTE-GALLONS

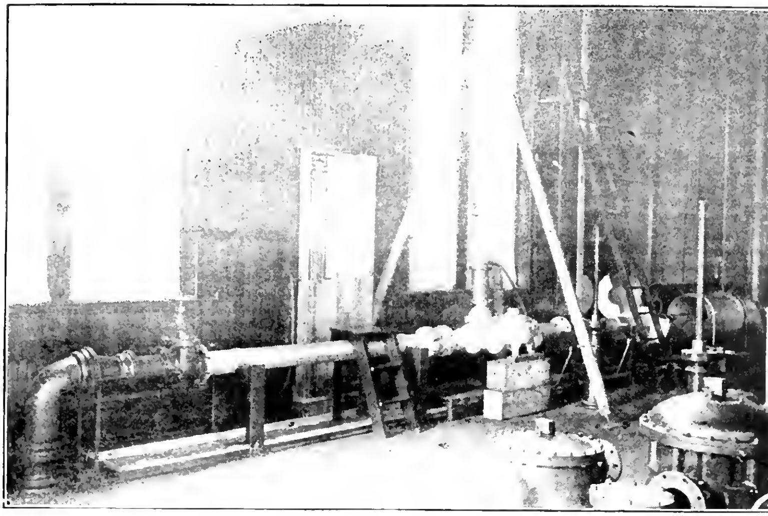


Fig. 1. Testing Apparatus.

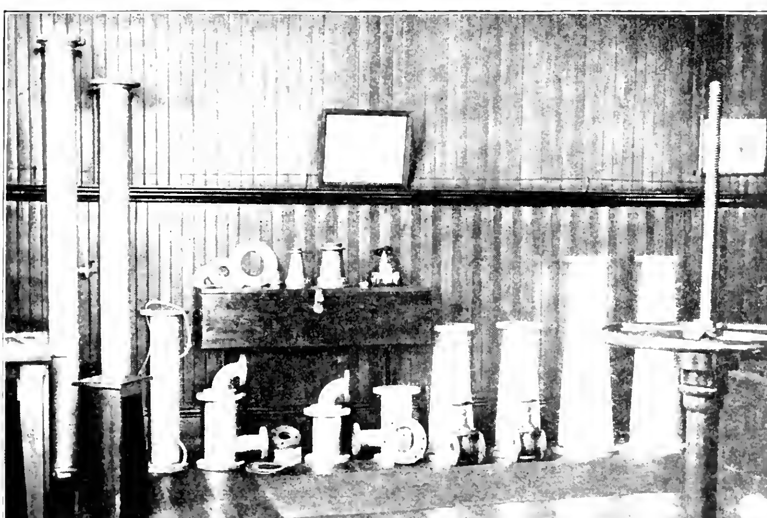


Fig 2. Group of Adapters.

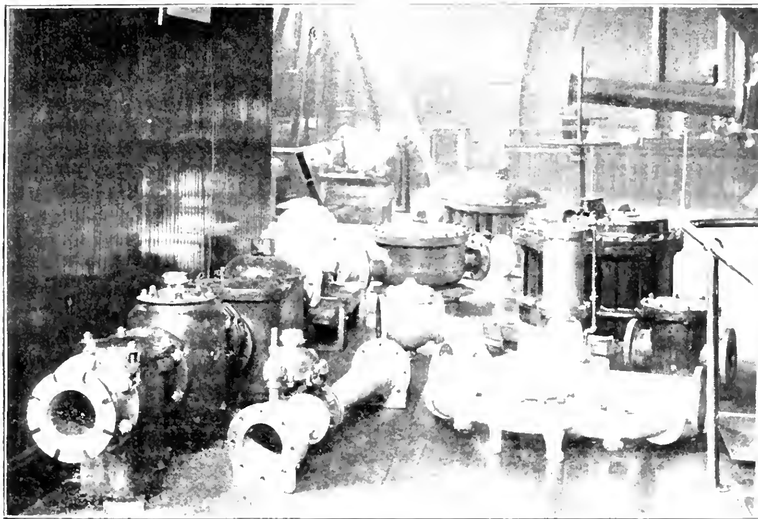


Fig. 1. Group of Meters to be Tested.

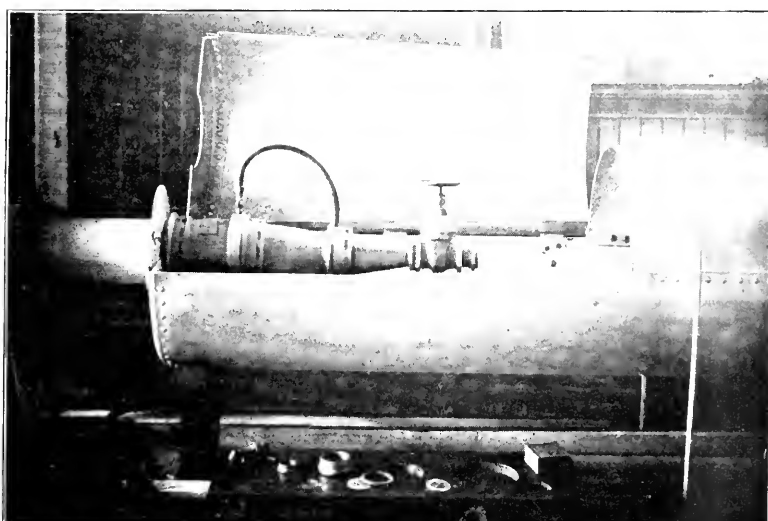


Fig. 2. $\frac{1}{4}$-inch Orifice discharging 9.64 Gallons per Minute.

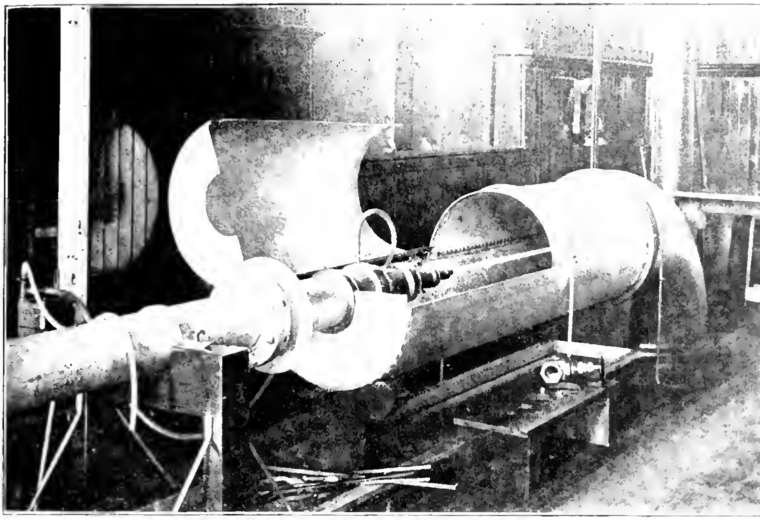


FIG. 1. ½-INCH NOZZLE DISCHARGING 56.8 GALLONS PER MINUTE.

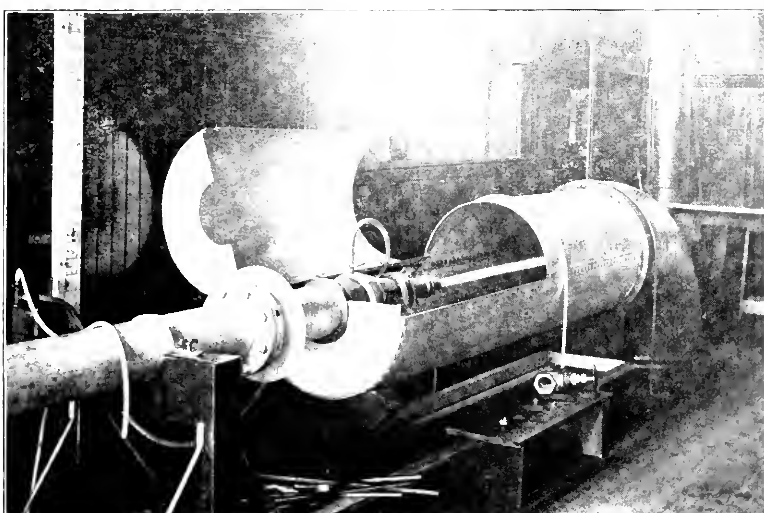


FIG. 2. 1-INCH NOZZLE DISCHARGING 227 GALLONS PER MINUTE.

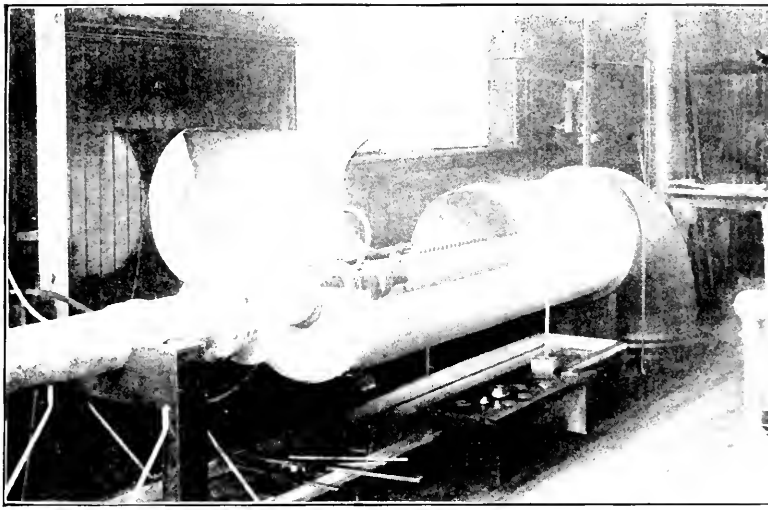


Fig. 1. 2-inch Nozzle discharging 893 Gallons per Minute.

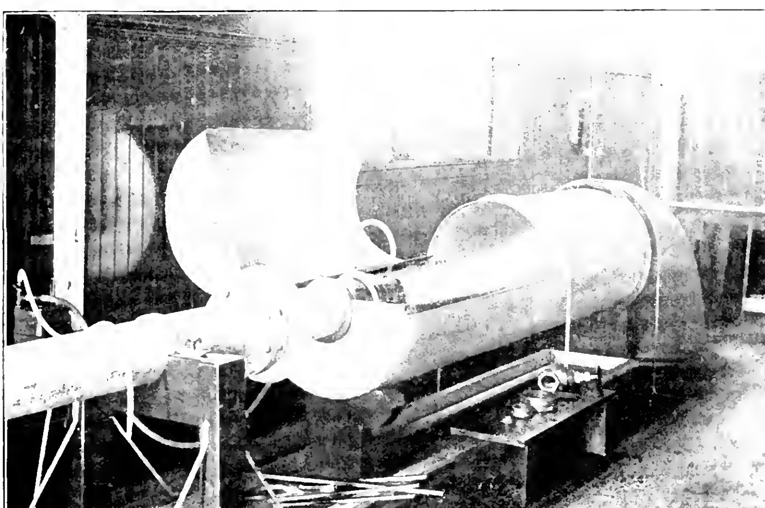
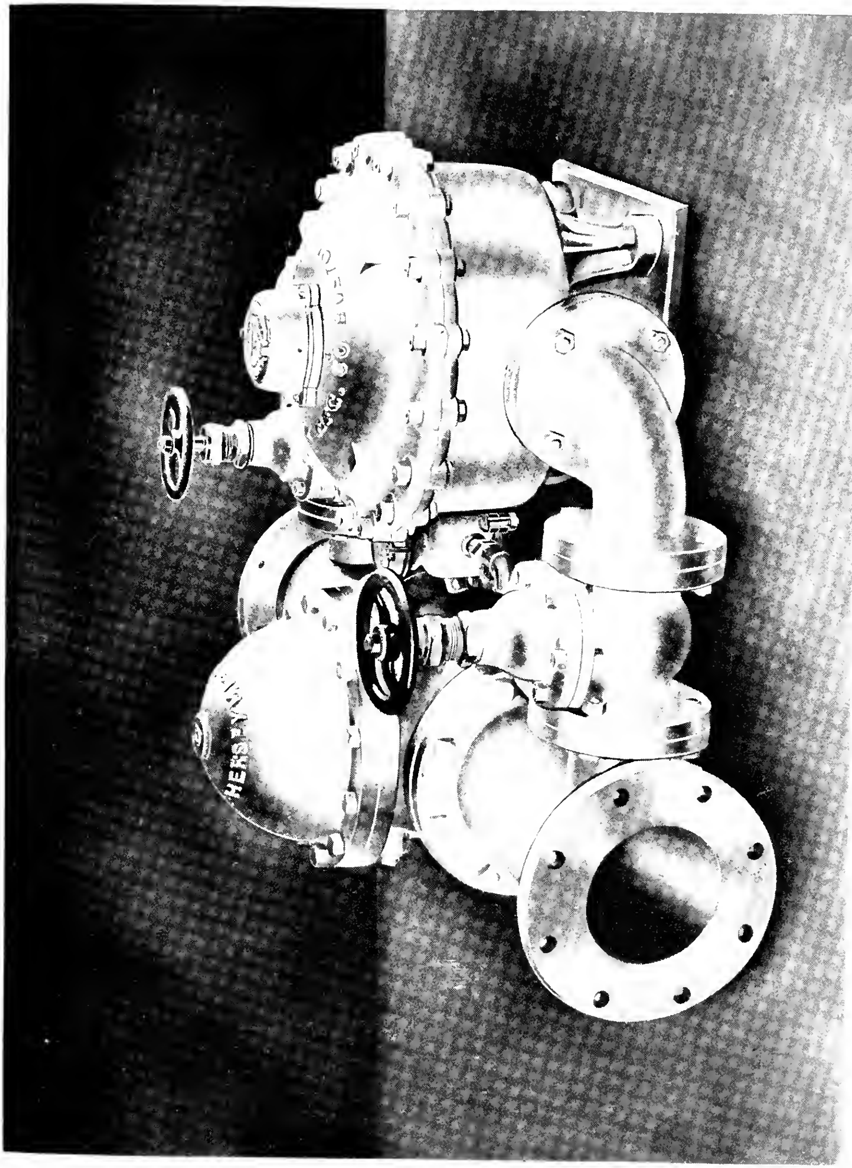


Fig. 2. 4-inch Nozzle discharging 2612 Gallons per Minute.



HERSEY DETECTOR METER.

mercury pot was one of the regular pattern, having a small glass window in the side permitting a comparison of the zero point of scale with mercury in the pot.

For measuring the retardation or loss of pressure in the meters, a mercury U-gage, placed in a cabinet and fastened to the wall, was used. The arrangement of the testing apparatus is shown in plan and elevation on Plate VIII.

To facilitate the work of testing, a complete collection of adapters was procured, including different lengths of 6-inch pipe and nipples, flanges with standard drilling, reducers, expanders, valves, etc. By the use of these adapters any machine from 3 inches to 12 inches can, in a short time, be inserted in the apparatus ready for testing. (Plate XI, Fig. 2.)

The following is a list of adapters employed:

2	pieces	6-inch	wrought-iron pipe,	8	feet long.
1	piece	"	"	" $7\frac{1}{2}$	" "
1	"	"	"	" 7	" "
1	"	"	"	" 6	" "
1	"	"	"	" 4	" "
1	"	"	"	" 3	" "
1	"	"	"	" 2	" "
2	pieces	"	"	" 1	foot "
2	"	"	"	"	short nipples.

2 6-inch x 3-inch flanged reducers.
2 6-inch x 4-inch " "
2 6-inch x 8-inch " expanders.
2 6-inch x 10-inch " "
2 6-inch x 12-inch " "
2 4-inch flanged elbows.
2 6-inch " "
2 6-inch gate valves.
2 3-inch " "
1 2-inch gate valve.
6 pairs drilled flanges.

The elevation of center of nozzles was 39.6 feet above city datum; the level of high water in the reservoir is 181.5 feet, thus giving a static head of 141.9 feet, or a pressure of about 61.4 pounds. Notwithstanding that the 12-inch pipe from the reservoir fed several laterals of the supply system, the pressures given by the mercury column were reasonably free from fluctuations.

In compiling data we were enabled to obtain easily and graphically, for purposes of comparison during each series of tests, the retardation by plotting the indicated loss of pressure on square root or second-power paper from plate made by Mr. J. A. Tilden, of the Hersey Manufacturing Company.

In finding the relation or difference between the meters and devices tested and straight plain pipe, the space usually occupied by the meter in the apparatus was fitted with a 3-foot "filling-in piece" of 6-inch pipe. Under this condition the quantity of water discharged and loss of head were obtained by the use of different sized nozzles, thus showing the available delivery and loss of pressure or friction in the apparatus, as follows:

TABLE No. 1.

Size of Nozzle or Opening.	Gallons discharged per Minute.	Loss of Pressure in Pounds.
4-inch	2 612	0.8
2 "	893	0.1
1 "	227	0.0
$\frac{1}{2}$ "	56.8	0.0
$\frac{1}{4}$ "	9.64	0.0
$\frac{1}{8}$ "	2.60	0.0
$\frac{1}{16}$ "	0.55	0.0

With tests under similar conditions, the above table permits a comparison of flows and loss of pressure between the meters and devices tested and the maximum discharge and minimum loss of pressure. The only correction necessary, and that is inappreciable, is for the difference in static head due to the slightly varying level of water in the reservoir.

The following brief description and summary of the meters tested may be of assistance in recognizing the functions of different types of meters and devices.

Six-Inch Crown Meter, with fish trap, manufactured by the National Meter Company. "The Crown is a rotary piston positive displacement meter"; the smaller sizes, in many places, are recognized as a standard for accuracy and durability. The maximum capacity of this meter under local conditions through a

4-inch nozzle was 1 109 gallons per minute, with a loss of pressure of about 49 pounds; the sensitiveness on $\frac{1}{8}$-inch and $\frac{1}{4}$-inch streams was 91.5 per cent.; on flows from 56 to 1 109 gallons, its accuracy was 98.75 per cent.

Six-Inch Nash Meter, special pattern with fish trap, made by the National Meter Company. The Nash is of the disk type, commonly called a positive meter. The disk is made of hard rubber, reinforced and strengthened with metal. While flushing the meter, preliminary to the test, and discharging about 1 100 gallons per minute, or 22 per cent. more than its rated capacity, the disk broke into six pieces, twisting and bending the metal reinforcement. The rated capacity of the meter is 900 gallons. With the broken disk the meter discharged 840 gallons, or only 6.6 per cent. less than the rated capacity. After removing the broken disk it was found that the capacity of the case was 1 540 gallons, with a loss of pressure of 39 pounds.

The broken disk was replaced by a new one and the discharge limited to the rated capacity, 900 gallons. With this flow the loss of pressure was 18.65 pounds. For accuracy on flows of 56 gallons and over, this meter registered about 99 per cent.; on discharges of 10 gallons, about 91 per cent., and $2\frac{1}{2}$ gallons, 55 per cent.

Six-Inch Union Rotary Piston Meter, manufactured by Union Water Meter Company, of Worcester. This meter is of the positive type, and has been well and favorably known by water-works people for over twenty-five years. " The meter is constructed of composition and consists of two pistons rotating in contact with each other upon vertical axes within a cylindrical chamber," each piston in turn being impelled by the elliptical gearing. This meter with double screened fish trap delivered 1 725 gallons per minute, with a loss of pressure of about 33 pounds. Removing the screens, the delivery was 1 930 gallons, with a loss of 25.75 pounds. Testing this meter again, by replacing the coarse strainer with an increased number of $\frac{1}{4}$-inch holes, we found that it was capable of passing 1 840 gallons per minute, with a loss of 28.6 pounds. This meter is large and bulky, its parts are solid and substantially made, yet a remarkable feature of this weighty machine is its ability to record 57.7 per cent. of the flow on $\frac{1}{4}$-inch streams, while on streams above $\frac{1}{4}$-inch the registration was about 100 per cent.

This meter was blocked by placing a small wedge between one of the pistons and the body of meter; the pistons in this position allowed 825 gallons to slip or pass through the meter, with an estimated loss of pressure of over 50 pounds.

Six-Inch Hersey Torrent Meter, with fish trap, manufactured by the Hersey Manufacturing Company, is of the current type. The piston is a balanced horizontal wheel, revolving on a vertical spindle by impact from the water which is directed against it by the deflector vanes. The revolutions are governed by the quantity of water passing, and communicate to a dial which indicates the measurements. On flows under 50 gallons per minute the registration is variable; between ½-inch and 4-inch streams the average registration is 99 per cent. The maximum capacity of this meter was 1 830 gallons per minute, with a pressure loss of 31 pounds.

The exterior appearance of this meter is small and compact, yet the interior is capacious; its working parts are simple and it can easily be regarded as a serviceable model of the current meter.

Six-Inch Crest Meter, manufactured by the Neptune Meter Company. This meter is of the current or velocity type. The makers claim a "more effective adaptation" of the helix or screw. To give greater or less sensitiveness, depending upon the relative degree of sensibility required, the propeller spaces can be made less or more. After some experiments under local conditions, including changes and adjustments of the working parts, this current meter made the remarkable record of registering 89 per cent. on a flow of 9½ gallons per minute, while the registration on the higher flows ranged from 92 to 103 per cent. The action of this meter, with fish trap, during some of the tests was slightly erratic. Without fish trap, this meter passed 2 070 gallons per minute with a pressure loss of 21.7 pounds; with fish trap, it delivered 1 905 gallons with a loss of 25.4 pounds.

Six-Inch Gem Meter, with fish trap, made and presented for testing by the National Meter Company. This meter is of the current propeller type, similar to many of the same kind now in use throughout the country. This meter was capable of delivering more water than any other 6-inch current meter tested, and with less loss of pressure; that is, 2 200 gallons per minute, with a loss of 15.9 pounds. It registered on flows above 50 gallons

99.12 per cent.; below 30 gallons the registration was neither constant nor substantially correct.

Ten-Inch Hersey Torrent, with fish trap, is a larger model of the 6-inch Torrent before mentioned. This meter delivers 2 410 gallons per minute with a net loss of 8 pounds; the accuracy on flows from 56 to 2 410 gallons was 96.1 per cent.

Twelve-Inch Giant Meter, manufactured and presented for testing by the Hersey Manufacturing Company. The design consists of a converging tube on inlet side and a diverging tube on outlet side, the two joined together with a throat piece having an annular core with openings into the tube. On top is placed a by-pass meter, so proportioned that one twentieth of the water passes through the meter and the other nineteen twentieths through the tube; the inlet to the by-pass meter was from the converging tube; and the outlet into the throat piece. During the first series of tests this meter registered on streams larger than ½ inch 94.8 per cent. The gearing was then changed and another series of tests made; the registration then showed about 104 per cent. The capacity of this meter was 2 490 gallons, with a net loss of 7.25 pounds.

Six-Inch Tilden Device, manufactured by the Hersey Manufacturing Company, and described in "Report of Committee on Private Fire Protection" to the New England Water Works Association, February, 1904, as follows:* "In the device submitted a 3-inch meter is set in a by-pass around a double-faced gate valve with parallel seats, the face toward the pressure being bored to admit of the passage of water through the same, and thence up around the stem into a cylindrical chamber directly above the valve, through the center of which the valve stem extends.

"In the cylindrical chamber, attached to the valve stem, is a cup-leather plunger, placed cup down or against the pressure, and weighted to such extent as with the weight of the valve and stem to constitute a force, tending to keep the valve closed, equal to the pressure per square inch which it is designed to absorb in the apparatus."

"The cup-leather packed valve-operating plunger is, as regards the pressure from the lower or inlet side, absolutely tight. The

* JOURNAL N. E. W. W. Ass'n, June, 1904, Vol. 18, p. 198.

valve itself is, as usual, a single-faced gate closed by the pressure. The pressure at the inlet, conveyed through the hole in the valve and up around the stem to the under side of the valve-opening plunger, is balanced by the pressure on the outlet side of the valve, the same being conveyed to the top of the plunger through a brass tube."

This device was designed to record accurately small flows, and yet be capable in the event of fire of delivering almost as much water as straight plain pipe. This device demonstrated its ability to discharge within 4½ per cent. of the available supply. With a static head of 61.4 pounds, it furnished 2 500 gallons per minute, with a loss of only 4.95 pounds. It further substantiated the claim made for it by recording 100 per cent. of the flow of all streams up to 157 gallons per minute, the opening point of the hydraulic gate valve; the loss of head at the opening point was 4.25 pounds.

The registration on flows from 157 to 2 500 gallons per minute ranged from 98 to 5.8 per cent. and the retardation from 7.9 to 4.95 pounds.

This device has been repeatedly set up and tested for exhibition purposes; on each and every occasion it has been positive in its action, and has not shown any tendency to stick, either while in actual operation or by the opening and closing of the small valve on the connection to the upper side of plunger.

Six-Inch Proportional Vertical Check Valve (experimental), submitted by the Hersey Manufacturing Company and designed by Mr. J. A. Tilden. As far as the registration on small flows is concerned, the province of this device is similar to the Tilden device just described, the only change being the elimination of what might be called the open-and-shut gate valve. This device consists of a 3-inch Hersey disk meter set in a by-pass around a vertical check valve placed in a horizontal line of 6-inch pipe. The principle of the valve is that a loss of 10 per cent. of the pressure on the outlet side opens the check and allows the water to flow through the run of 6-inch pipe in addition to what is passing through the by-pass meter. These results are obtained in the following manner: A brass check fits on a ring seat, also on a 2-inch tube which has an outlet to the atmosphere through a

telltale meter; a guided spindle extends above and below the seat insuring a reseating of the check. The difference in area of upper and lower surfaces of the check is over 10 per cent. In practice, this check remained closed until the difference in pressure was 6.3 pounds, or, in other words, until the by-pass meter delivered 191 gallons per minute, when the check opened and the frictional loss dropped to 0.2 of a pound.

The accuracy of the by-pass meter on flows from ½ gallon to 191 gallons per minute was 101.6 per cent. This device delivered 2 065 gallons per minute with a pressure loss of 20.65 pounds. These results are reasonable, considering the narrow and tortuous water passages. The telltale meter serves as an indicator, and while the check is open from any cause discharges water.

Six-Inch Differential Swing-Check Device (experimental), designed by Mr. J. A. Tilden, of the Hersey Manufacturing Company. The purpose of this device is to accurately record small flows and to detect large flows by means of the telltale meter attachment, even to the extent of approximating the water used during a fire, also to reduce the loss of pressure when large quantities of water are needed, so that the retardation will be unimportant in case of an emergency. In principle the arrangement is similar to the proportional vertical check, except that in place of the vertical a swing check is inserted in the pipe line. An annulus or groove opening to the atmosphere, to which may be attached the telltale meter, is cut into the inclined brass seat in place of the two-inch tube in the vertical check.

The inlet and outlet areas of the swing gate exposed to the pressures are so proportioned that when there is a loss of 3.3 pounds on the outlet side, or, to express it in another way, when 128½ gallons per minute flow through the by-pass meter, the swing check opens and the frictional loss is reduced to about 0.2 of a pound. With a loss of scarcely 4¼ pounds, this device delivered 2 495 gallons per minute.

During the first series of tests this device operated satisfactorily, while in the second series the telltale, with no water discharging from the nozzle, indicated that either the check did not cover the annulus or else the check did not completely close. An inspection showed only a very slight wear of the rubber face of the check.

If this condition should arise in actual practice it would be difficult to determine whether it was a leakage into the annulus, or, where the fire-service piping system is concealed, how much water was being wasted. This seems to be an inherent defect in this particular swing-check device. With this device there is no pointer or indicator to show the degree of opening of the check.

Four-Inch Swing-Check Device (experimental) is a smaller size and similar in construction and purposes to the previously described device. In place of the 6-inch a 4-inch swing check is used, and in place of a 3-inch a 2-inch disk meter is placed on by-pass.

The capacity of this appliance is 2 100 gallons per minute, with a net loss of 21 pounds in pressure.

The by-pass meter registers about 100 per cent. of the flow on streams discharging from ½ gallon to 41 gallons, the opening point of the check. The indicated loss of pressure just as the check is about to open is 3.65 pounds, when simultaneously with the opening the U-gage shows a loss of only 0.3 of a pound. Following the opening of check, and while discharging 41 gallons, the by-pass meter registered 27 per cent.

The check, having opened automatically with a draught of 41 gallons per minute, did not close again until the water was entirely shut off, and then only by quickly closing the valve and giving it a jar or shock, thus showing that during a portion of the experiments the telltale was misleading, in so far as it continued to discharge water when no water was being used at the outlet.

NOTE, August 18, 1905. Since the foregoing tests were made the Hersey Manufacturing Company have presented for testing at Lowell a Hersey Detector Meter. In appearance and arrangement it is similar to the 6-inch experimental differential swing-check device previously described, except that in place of the "stock" checks, with their inherent defects, it has a specially designed check valve, with a weighted flapper consisting of a hollow brass ball inside the case; if desired, the ball can be weighted with shot, thus varying the opening point of the check, and also enabling the check to close more readily when the flow is reduced.

This device, which is shown in Plate XV, is looked upon favorably by many water-works men and insurance underwriters.

The following is a summary of the tests.

SIX-INCH HERSEY DETECTOR METER WITH IMPROVED CHECK VALVE. BRASS BALL NOT WEIGHTED. METER NO. 233,288. JULY 29, 1905.

Size of Nozzle or Opening.	Gallons per Minute by Nozzle.	Per Cent. Registration on By-Pass Meter.	Loss of Pressure. Pounds.	Remarks.
4-inch	2 460	2.9	2.36	Check open.
2 ,,	857	4.3	0.5	,, ,,
1 ,,	220	19.9	0.45	,, ,,
1 ,,	126	100.0	3.5	Opening point of check.
1 ,,	128	35.5	0.45	Just after opening.
1 ,,	49	100.0	0.45	Closing point of check.
1 ,,	47.7	100	0.5	Just after closing.
½ ,,	56.5	99.6	0.6	....
¼ ,,	9.64	99.5	0.0	....
⅛ ,,	2.6	99.0	0.0	....

SIX-INCH HERSEY DETECTOR METER WITH IMPROVED CHECK VALVE. BRASS BALL WEIGHTED WITH 12-LB. OF SHOT. METER NO. 233,288. AUGUST 9, 1905.

Size of Nozzle or Opening.	Gallons per Minute by Nozzle.	Per Cent. Registration on By-Pass Meter.	Loss of Pressure. Pounds.	Remarks.
4-inch	2 460	2.87	2.45	Check open.
2 ,,	868	5.68	0.8	,, ,,
1 ,,	221	26.6	0.8	,, ,,
1 ,,	139.5	100.0	4.11	Opening point of check.
1 ,,	145	42.8	..	Just after opening.
1 ,,	63.6	100.0	0.77	Closing point of check.
½ ,,	56.5	99.6	0.75	....
¼ ,,	9.64	99.5	0.0	....
⅛ ,,	2.6	99.0	0.0	....

Table No. 2 shows the sensitiveness and accuracy of the meters in per cent. of recorded flow, also the flow of different size nozzles.

In Table No. 3 is shown the retardation or loss of pressure with different flows, due to the resistance offered by the meter "dependent upon the intricacy and size of its water passages and the friction of its moving parts."

Plate IX is intended to show, by comparison, the relative recorded flows of the large meters and special fire-service devices.

Plate X shows, on profile paper, the loss of pressure or retardation in meters and fire-service devices.

In a synopsis of the tests we find in the three types of meters represented, the positive displacement, the current, and the special devices:

First. That the 6-inch positive meter is adapted for close registration on all appreciable flows up to its capacity; the average capacity of this type being only 54 per cent. of the available supply through a 6-inch pipe, while the loss in pressure over plain pipe is 3 900 per cent., or in the ratio of 39 to 1.

These figures show that placing a positive meter on a single fire service, designed to furnish water for a certain number of fire-extinguishing fixtures, would be a menace to the risk, unless arranged in parallel or in conjunction with other devices.

Second. That the 6-inch current, velocity or inferential meter is better suited to deliver larger quantities with less loss of head than the positive type. The average current meter will deliver 75 per cent. of the available supply with a loss of 3 062 per cent., or in the ratio of 30.62 to 1, in pressure, excelling the positive meter 21 per cent. in efficiency of flow, and 838 per cent. in loss of head.

Yet this type of meter is not capable, like the positive meter, of standing guard over water-department interests, for the reason that it is unreliable on flows under 50 gallons per minute, or, to express it in another way, most current meters cannot be depended upon to record streams as small as 1-16 inch, $\frac{1}{8}$ inch, $\frac{1}{4}$ inch and sometimes $\frac{1}{2}$ inch with any degree of accuracy.

Types	Meters	1/16 inch opening Gals per Min	1/16 inch opening Per Cent	1/8 inch opening Gals per Min.	1/8 inch opening Per Cent	1/4 inch opening Gals per Min.	1/4 inch opening Per Cent	1/2 inch Nozzle Gals per Min	1/2 inch Nozzle Per Cent	1 inch Nozzle Gals per Min.	1 inch Nozzle Per Cent	2 inch Nozzle Gals per Min.	2 inch Nozzle Per Cent	4 inch Nozzle Gals per Min.	4 inch Nozzle Per Cent	Remarks
Positive	6" Crown	.549	0.06	2.6	89.0	9.64	94.3	56	99.6	220	101.2	708	98.64	1109	95.59	With Fish Trap
	6" Nash (broken disc)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	6" Nash	.549	0 0	2.6	55.0	9.64	91.1	56.6	100.1	225	99.0	775	97.3	900	98.2	With Strainer
	6" Union	.549	0.0	2.6	19.9	9.64	68.2	56.5	101.85	226	103.1	823	100.1	1722	99.15	With Fish Trap
	6" Union	.549	0.0	2.6	0.3	9.64	34.4	56.1	98.5	226	101.5	840	99.18	1930	97.8	Without Fish Trap
	6" Union	.549	0.0	2.6	0.8	9.64	70.8	56.6	103.3	227	102.3	837	100.1	1840	99.3	Single Screen
	6" Union	—	—	—	—	—	—	—	—	218	—	615	—	825	—	(Blocked)
Current	6" Crest	.549	0 0	2.6	0 0	9.64	0.0	57	87.3	228	96.9	860	90.5	2063	90.1	Hemp wound in gears
	6" Crest	.549	0 0	2.6	0.0	9.64	91.5	56.6	103.3	226	101.7	852	98.5	2040	98.8	Without Fish Trap
	6" Crest	—	—	—	—	9.64	88.2	56.5	103.5	225	94.2	840	92.3	1905	97.3	With Fish Trap
	6" Gem	.549	0.0	2.6	0 0	9.64	64.1 0.0	57	102.1	227	99.72	860	97.57	2200	97.1	With Fish Trap
	6" Torrent	.549	0 0	2.6	0 0	9.64	9.5	57	95.6	228	99.9	843	100.6	1830	99.6	With Fish Trap
	6" Torrent	.549	0.0	2.6	0 0	9.64	52.8	56.2	95.8	223	100.1	828	100.4	1775	99.6	Special tapered spindle
	10" Torrent	.549	0.0	2.6	0 0	9.64	0 0	56.2	90.45	228	99.55	876	97.1	2405	97.4	With Fish Trap
Devices	4" Detector Meter	.549	100.9	2.6	102	9.64	100.3	56.5	20.3	227	5.2	862	4.1	2100	3.8	Swing Check Valve With 2" Hersey Disc on B.P.
	6" Detector Meter	.549	109.2	2.6	100	9.64	99.5	56	99.7	225	15.15	876	4.74	2490	4.28	Swing Check Valve With 3" Hersey Disc on B.P.
	12" Giant	—	—	—	—	—	—	57	90.1	228	101	885	94.7	2490	93.4	Before change of gears
	12" Giant	—	—	—	—	—	—	—	—	149	109.7	885	102.3	2480	101	After change of gears
	6" Proportional C.V.	.549	109.2	2.6	100	9.64	99.5	56.1	99.75	225	18.55	851	14.85	2065	14.85	Vertical Check (Globe Pat.) 3" Hersey Disc on B.P.
	6" Tilden Device	.549	103	2.6	99.15	9.64	99.9	56.8	99.0	220	77.3	830	25.6	2490	5.8	Hydraulic Gate Valve 3" Hersey Disc on B.P.
	Space Piece	—	—	—	—	—	—	56.8	—	226	—	895	—	2612	—	3 ft 6" W. I. Pipe

TABLE No. 2. Nozzle Discharges for Different Sized Streams, and Per Cent. of Meter Discharge to Nozzle Discharge.

To illustrate wastes on small streams:

1–16-inch stream will discharge	790	gallons per day.
$\frac{1}{8}$-inch " " "	3 744	" " "
$\frac{1}{4}$-inch " " "	13 881	" " "
$\frac{1}{2}$-inch " " "	81 792	" " "

The cost of such flows at 12 cents per 100 cubic feet, the average price of metered water at Lowell, would be, for a year,

1–16-inch stream	$46.16
$\frac{1}{8}$-inch "	218.79
$\frac{1}{4}$-inch "	811.20
$\frac{1}{2}$-inch "	4 779.92

showing that many small wastes could become burdensome to a department. Then, how can current meters be used and at the same time get the record of the small wastes?

As a suggestion, one way would be to set a current meter of known efficiency that will record the flows above a certain amount, but before this meter is set and while the pipe line is cut for such setting, or, better still, if a reliable gate valve is convenient, place a small meter on a by-pass or loop for a time, and by this means obtain the small inherent wastes of the private system, and apply this as a constant to the current meter.

Third. The 6-inch special fire-service devices, so called, are expressly made to register the deceptively small streams and to record wastes or uses up to the opening point of such device; beyond that the devices presented could only indicate that the gate or check had opened, but the degree and duration of such opening could not be recorded.

The competency of these devices may be shown by the following facts — the available supply of water through the apparatus for testing was 2 612 gallons per minute.

The 6-inch Tilden Device was capable of delivering	95 per cent.
The 6-inch Swing-Check Device was capable of delivering	95 per cent.
The 6-inch Globe Check Device was capable of delivering	79 per cent.
The 4-inch Swing-Check Device was capable of delivering	80 per cent.

Gallons Per Minute Flowing through Meter Discharged at Nozzle	Space Piece 3 ft 6" W.I. Pipe	Positive Meters							Current Meters							Meter Devices					
		6" Crown Meter With Fish Trap	6" Nash Meter Disc taken out	6" Nash Meter With Fish Trap	6" Union Meter With Fish Trap Double Screen	6" Union Meter Without Fish Trap	6" Union Meter With Fish Trap Single Screen	6" Union (Blocked) With Fish Trap Single Screen	6" Crest Meter With Fish Trap	6" Crest Meter Without Fish Trap	6" Crest Meter Without Fish Trap After change of gears	6" Gem Meter With Fish Trap	6" Torrent Meter With Fish Trap	6" Torrent Meter With Fish Trap (new spindle)	10" Torrent Meter With Fish Trap	4" Detector Meter (Swing Check)	6" Detector Meter (Dif. Swing Check)	12" Giant Meter June 1, 1904	12" Giant Meter June 2, 1904	6" Proportional Check Valve (Globe Pattern)	6" Tilden's Hydraulic Gate Valve
50	.005	0.2	0.05	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.25	0.3	0.0	0.0	0.0	0.6
100	.010	0.4	0.20	0.6	0.1	0.0	0.10	0.7	0.1	0.0	0.0	0.0	0.1	0.1	0.00	0.30	2.2	0.0	0.0	0.0	1.3
150	.015	1.0	0.40	0.8	0.2	0.1	0.2	1.7	0.2	0.1	0.1	0.1	0.2	0.2	0.05	0.35	0.2	0.0	0.0	0.1	3.7
200	.020	1.6	0.70	1.1	0.3	0.2	0.33	3.1	0.3	0.2	0.2	0.15	0.35	0.35	0.07	0.40	0.22	0.0	0.0	0.2	4.0
250	.025	2.5	1.00	1.3	0.5	0.35	0.50	5.0	0.4	0.3	0.3	0.2	0.5	0.6	0.10	0.45	0.23	0.0	0.0	0.3	5.2
300	.030	3.6	1.40	2.0	0.8	0.5	0.70	7.0	0.55	0.4	0.4	0.35	0.8	0.9	0.14	0.55	0.24	0.1	0.1	0.4	5.5
350	.035	5.0	2.00	2.7	1.1	0.7	1.00	9.0	0.75	0.5	0.6	0.4	1.1	1.2	0.20	0.75	0.26	0.15	0.15	0.5	5.7
400	.040	6.4	2.60	3.6	1.6	1.0	1.30	12.2	1.1	0.7	0.6	0.5	1.3	1.6	0.25	1.00	0.28	0.2	0.2	0.6	5.9
450	.045	8.0	3.20	4.5	2.0	1.3	1.70	15.1	1.3	0.9	0.9	0.6	1.7	2.0	0.30	1.20	0.30	0.25	0.25	0.9	6.0
500	.051	10.1	4.00	5.5	2.5	1.6	2.10	19.3	1.7	1.2	1.2	0.8	2.2	2.5	0.35	1.40	0.31	0.3	0.3	1.2	6.1
550	.057	12.0	5.00	6.8	3.1	2.0	2.50	23.5	2.1	1.5	1.5	1.0	2.7	3.1	0.40	1.60	0.33	0.35	0.35	1.4	6.2
600	.063	14.5	6.00	8.1	3.8	2.3	3.0	28.0	2.5	1.8	1.8	1.2	3.3	3.7	0.45	2.00	0.37	0.4	0.4	1.7	6.4
650	.069	17.0	7.00	9.5	4.3	2.8	3.5	33.0	2.9	2.1	2.1	1.5	3.9	4.3	0.50	2.30	0.41	0.45	0.45	2.0	6.9
700	.076	20.0	8.00	11.1	5.0	3.2	4.0	38.0	3.3	2.4	2.4	1.8	4.5	5.0	0.60	2.70	0.45	0.5	0.5	2.3	7.0
750	083	23.0	9.10	13.0	6.0	3.8	4.6	44.0	3.8	2.8	2.7	2.0	5.1	5.8	0.70	3.00	0.50	0.55	0.55	2.7	7.2
800	090	26.0	10.20	14.9	6.8	4.2	5.2	50.0	4.4	3.2	3.0	2.2	5.8	6.1	0.85	3.30	0.56	0.6	0.6	3.1	7.4
850	.097	29.0	11.50	16.2	7.6	4.8	6.0		5.0	3.6	3.4	2.5	6.5	7.5	1.00	3.70	0.60	0.65	0.65	3.5	7.7
900	.104	33.0	13.1	18.6	8.3	5.4	6.8		5.6	4.0	3.9	2.8	7.2	8.4	1.15	4.10	0.60	0.8	0.8	3.9	7.9
950	116	36.5	14.7		9.1	6.1	7.6		6.2	4.4	4.4	3.1	8.0	9.3	1.30	4.50	0.64	0.95	0.9	4.3	7.7
1000	.132	40.8	16.1		10.2	6.8	8.2		6.9	5.0	4.8	3.4	9.0	10.2	1.45	5.00	0.68	1.1	1.1	4.8	7.4
1050	.146	44.3	18.0		11.2	7.5	9.1		7.6	5.5	5.2	3.7	10.0	11.2	1.60	5.50	0.70	1.2	1.2	5.2	7.3
1100	.160	49.0	19.7		12.7	8.1	10.1		8.3	6.0	5.7	4.0	11.0	12.3	1.75	6.10	0.80	1.3	1.3	5.7	7.2
1150	.174		21.4		14.0	9.0	11.1		9.1	6.5	6.2	4.3	12.0	13.7	1.90	6.60	0.90	1.4	1.4	6.2	7.1
1200	.186		23.3		15.1	9.9	12.1		10.0	7.1	6.8	4.6	13.0	15.0	2.05	7.10	1.00	1.55	1.55	6.9	7.1
1250	200		25.1		16.2	10.5	13.1		10.9	7.7	7.4	5.0	14.0	16.0	2.20	7.70	1.10	1.7	1.7	7.6	7.0
1300	.220		27.3		17.9	11.4	14.1		11.8	8.3	8.0	5.4	15.1	17.2	2.35	8.30	1.20	1.85	1.85	8.1	7.0
1350	.240		29.5		19.0	12.2	15.1		12.7	9.0	8.6	5.9	16.3	18.8	2.55	9.00	1.30	2.05	2.05	8.9	7.0
1400	.260		31.8		20.8	13.1	16.3		13.6	9.8	9.2	6.4	17.8	20.2	2.75	9.70	1.40	2.2	2.2	9.5	6.9
1450	.280		34.1		22.0	14.1	17.6		14.5	10.5	9.9	6.9	19.0	21.8	3.00	10.3	1.50	2.35	2.35	10.2	6.8
1500	.300		36.5		23.9	15.2	19.0		15.5	11.2	10.6	7.2	20.7	23.4	3.20	11.0	1.60	2.5	2.5	10.9	6.7
1550	.314		39.0		25.0	16.2	20.4		16.5	11.9	11.3	7.8	22.0	25.0	3.40	11.7	1.70	2.65	2.65	11.6	6.6
1600	.328				27.0	17.3	21.8		17.6	12.8	12.0	8.3	23.3	26.8	3.70	12.4	1.80	2.80	2.80	12.2	6.5
1650	.342				28.8	18.4	23.1		18.8	13.7	12.8	8.9	24.9	28.4	3.90	13.1	1.90	3.0	3.00	13.1	6.4
1700	.356				30.8	19.7	24.5		20.0	14.5	13.7	9.3	26.2	30.0	4.10	13.9	2.00	3.2	3.2	13.9	6.2
1750	.370				32.8	20.9	25.9		21.1	15.3	14.6	10.0	28.0	32.0	4.30	14.7	2.10	3.4	3.4	14.8	6.1
1800	.384					22.1	27.4		22.3	16.0	15.5	10.5	29.8	33.9	4.50	15.5	2.20	3.6	3.65	15.7	6.1
1850	.400					23.2	29.1		23.7	17.0	16.3	11.1	31.4	35.5	4.80	16.3	2.30	3.8	3.80	16.6	6.0
1900	.420					24.7			25.0	18.0	17.1	11.7	33.0	37.5	5.10	17.1	2.40	4.0	4.0	17.5	6.0
1950	.440					26.0			26.5	19.0	18.0	12.3			5.30	18.0	2.50	4.3	4.3	18.4	5.9
2000	.460									20.0	19.0	13.0			5.60	19.0	2.70	4.6	4.6	19.3	5.9
2050	.480									21.0	20.0	13.6			5.90	20.0	2.90	4.8	4.8	20.2	5.8
2100	.500											14.2			6.20	21.0	3.00	5.0	5.0	21.1	5.8
2150	.530											15.0			6.50		3.20	5.2	5.2		5.6
2200	.560											15.8			6.90		3.40	5.4	5.4		5.5
2250	.590														7.20		3.60	5.6	5.6		5.4
2300	.620														7.40		3.70	5.9	5.9		5.3
2350	.650														7.70		3.90	6.2	6.2		5.2
2400	.680														8.00		4.00	6.4	6.4		5.1
2450	.710														8.40		4.10	6.7	6.7		5.1
2500	.740														8.80		4.20	7.0	7.0		5.0
2550	.770																				
2600	.800																				

Table No. 3. Retardation or Loss of Pressure in Water Meters.

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The same devices retarded the flow of water more than a straight piece of 6-inch pipe, as follows:

The 6-inch Tilden Device	625 per cent. or	1 to 6.25
The 6-inch Globe Check Device .	2 581 ,, ,, ,,	1 ,, 25.81
The 6-inch Swing-Check Device,	525 ,, ,, ,,	1 ,, 5.25
The 4-inch Swing-Check Device,	2 625 ,, ,, ,,	1 ,, 26.25

These figures show that some of the special devices can be depended upon to deliver more water with less loss of pressure than either the positive or current type of meter; that the devices are capable of recording the flows for which they are adjusted, but beyond such adjustment the flows can only be approximately accounted for.

In conclusion, we believe that if metering appliances were placed on all private supplies it would effectually put a stop to chronic wastes, and, in our opinion, there would no longer be any need for the department to supervise and inspect the fire service beyond such device, placing upon the parties protected by these fire services the responsibility of ascertaining the inherent leaks of the hidden portions of the fire-service system; for, undoubtedly, the party having to pay the bills will be inclined to stop such wastes, even to the extent of relaying and renewing the underground furniture and fixtures.

Whether or not we have partially fulfilled the expressed purpose of these tests, which was to discover, if possible, some practical mechanism to regulate and account for water taken from the distribution system — whether or not any of these meters or devices will satisfy the water-works people and fire underwriters, we will leave to the opinion of those interested in this important subject.

DISCUSSION.

Mr. Edward Atkinson.* It is such a discussion as this which justifies me, as an underwriter, in being a member of this Association. I appreciate to the fullest extent the extreme value to the mutual underwriters, whom I represent, of this investigation in Lowell, with which we are perfectly familiar. It reminds me,

* President, Boston Manufacturers Mutual Insurance Company.

however, of the tests of the ships of war which they have to pass in order to be accepted. They reach the required speed after every possible provision has been made, and are accepted. After that, in practice, they very rarely, if ever, attain any such speed, the conditions in practice being so thoroughly different from the conditions in such a carefully prepared test.

I wish to correct one error, if I may call it so, that but one fire service is needed. We represent the largest part of the large factories and workshops of the New England and Middle States and many others. Not in one case in one hundred do we accept a single supply of water. In many of the larger cities a double supply of water is required, and in many of the larger cities a double fire service.

Now, it turns out even in these refined tests that meters got clogged, that they broke, and that they did in some instances make an appreciable and what might be a disastrous reduction in the pressure. Bear in mind that in the emergency of a fire there come sudden changes of pressure, sudden conditions of emergency, and it goes without saying that any apparatus of any kind, however constructed, however well made, under those conditions may break and may prevent the saving of property. Our end is the same. Is it more important to the community to save a little water that might otherwise be wasted, or to save the property on which the whole welfare of the community may depend? There we come together.

Reference has been made to Mr. Freeman. When I first began my practice there was nothing but empiricism in pumps, pipes, hydrants, hose; and Mr. John R. Freeman was brought into the service of the mutual underwriters in order to bring about scientific results, and to bring these matters to the condition of applied science. Whether he was well chosen or not, his works have told. There has been no question of greater difficulty than the adjustment of the relations between underwriters of our kind, for the welfare of the community, and of the owners of factories, and the water-works engineers whose duty it is to save the water. In some cases, very rarely indeed, they have been so obstinate in demanding meters where they should not be installed, that the owners have dropped the public supply of water entirely, and

have put up their own independent works with their double supply of water. As a rule we rarely have any difficulty in getting a by-pass or in so arranging the meter that our fire service shall not be interrupted by any complex mechanism or any of the clogging that is liable to happen at any time except during such an experimentally refined test as has been described. The finality, unless it can be made satisfactory, simply is that we withdraw our policies. We have no money to make, all we aim to do is to save the community and the factory, and if they do not choose to accept our conditions, we simply withdraw our policy. We have nothing to sell.

Now, when the water-works engineers convince Mr. Freeman and my vice-president, Mr. Gray, and Mr. French who is here, that a meter can be put into a fire pipe without a by-pass, or without getting around it in some way, so that it shall be as safe with it in the fire service as without it, then we may accept it. Until then we mutual underwriters, who have fifteen hundred millions of property running from a minimum of 100 000 on a risk up to six or seven millions, stand in the way of the adoption of meters in a fire service, and shall continue to get around them, evade them or do without them, or do away with the water works which insist upon them. Our interests are identical, and the question is, will you save the most by saving a little water by putting in a meter, or will you save the welfare of the community by meeting that waste in some other way, as it has been met by Mr. Coggeshall in New Bedford, without impeding the fire service?

The President. We have a very long program for the afternoon, and it has been suggested that discussion of this paper be held over until our next meeting, and that we proceed now with the other papers. This paper will then be before you in print, and you can discuss it more fully.

[*September 13, 1905.*]

Mr. Sullivan. At the meeting in March, after the reading of the paper and the conclusion of the remarks of the gentleman who was discussing it, as I was about to reply, the President said, "We have a very long program for the afternoon, and it has been

suggested that discussion of this paper be held over until our next meeting."

At the former meeting Mr. Atkinson, in discussing the tests at Lowell, referred to the acceptance tests of warships. Now, gentlemen, I believe the results at Manila and Santiago justified the government in accepting warships after trial tests, and Captain Clark's memorable trip on the *Oregon* proved conclusively that a war ship in practice can measure up to a warship in theory.

It seems to me, however, that there is no very close analogy between the duties of a warship and a meter, between the speed of a boat and the capacity of a measuring device, the efficiency of the engines and the registration of a meter; but, like the tests of warships, the test of meters will show which is most suitable for special work. Again, ships of war are either accepted in entirety or provisionally, and are sometimes rejected on account of such tests. In the tests at Lowell, the meters were neither accepted nor rejected, but an honest endeavor was made to obtain facts that would assist and enlighten the department, and as some members of this Association were interested in the results, I was requested to prepare this paper.

I do not believe the experiments could be called "a carefully prepared test," and the meters and devices tested were either regular commercial meters from stock, in the market for sale, or experimental devices sent to us on account of the facilities we had for testing.

As for the charge of refinement of accuracy, I presume that the meter companies will admit that the machines sent out were well and carefully made; and as for trying to obtain the correct discharges and loss of head due to the meters, we have only emulated the example of the mutual underwriters, who have such scientifically equipped laboratories for testing almost everything employed in the extinguishment of fire. The able and excellent paper by Mr. French shows that they are fully alive to the issue, and cannot only make refined tests of meters, but can design and manufacture such a meter as Mr. French has described here; and I assure you I think he is modest in his claims with regard to its performance. It seems to me that it is such a meter as has long

been sought for by the different interests, and will supply a long-felt want.

Mr. Atkinson in his remarks said, "I wish to correct one error, if I may call it so, that but one fire service is needed." It must be that the gentleman misunderstood me. I said, "Out of one hundred and twenty-four fire services in Lowell only one was metered," and that was true at the time. Since then others have been added.

Mr. Atkinson, continuing, said, "It turned out even in these refined tests that meters got clogged, that they broke, that they reduced the pressure, etc." Why, that was part of the object and aim of these tests, to gather just such information, and I believe it is the object and aim of the underwriters to get such information.

Mr. Atkinson further says, "It goes without saying that any apparatus of any kind, however constructed, however well made, may break and may prevent the saving of property." Granting that, is the chance of a properly constructed meter breaking down and being a menace any greater than the chance of a valve being closed or failing to operate, a hydrant not opening, fire pumps not doing their duty, sprinkler-heads failing to open at the proper time or the piping systems failing to withstand the pressure? Mark you, gentlemen, there was no time during the tests, whether a meter clogged or broke, that the supply of water was entirely shut off.

Now, in regard to the welfare of the community, and looking at it from the road, as it were, it strikes me that water-works managers have the welfare of the community as much at heart as any other body of men.

I do not believe it was the intent of the Lowell Water Department to install a testing apparatus to make any series of refined tests. It was rather to install a practical and useful apparatus that can be used at any and at all times for testing large meters.

Professor Bemis spoke about the effect of water-hammer on the Hersey Detector Meter. We made a series of tests both on the experimental and improved detector meter; and the water for these tests was taken from a pipe line supplying a high-service pump, pumping direct to the high-service system, during a portion of the year. This pump had a regulator, and relieved itself

through a relief valve located in the basement of the engine room, thus making the conditions favorable for water-hammer. On every occasion when the check was once closed it remained closed, and no water-hammer was experienced sufficient to open it. I believe that the by-pass furnished sufficient compensation to keep the clapper on its seat.

FIRE-SERVICE METERS.

BY E. V. FRENCH, ENGINEER AND INSPECTOR, ASSOCIATED FACTORY MUTUAL INSURANCE COMPANIES, BOSTON, MASS.

[*Read September 13, 1905.*]

Several years ago, after many discussions, in this Association and elsewhere, of the problems which the private fire service causes, we came to the conclusion that the best solution of all of the difficulties would be a meter which would measure *all* the water passing through the service, but which could not seriously obstruct the flow. There was no meter on the market fulfilling these requirements and there appeared no immediate prospect of one being developed. As we felt that something must be done soon, we started to devise a meter for this work.

We believed then, and we still believe, that there are many cases where it is not yet necessary to put on a meter to prevent improper use of water from the fire system. We have therefore felt justified in urging that simpler means be adopted for the present in all cases where conditions are favorable. Later, when devices now promising well have been proved by experience to do the work satisfactorily there will be little objection, other than the cost, to the somewhat general equipping of fire services where there is considered to be a real need of it.

Some form of proportional meter seemed the most hopeful direction for a solution of the problem. We have made, and others have made, many experiments using an ordinary check valve having a by-pass around it with a meter in the by-pass. This arrangement would measure large flows with reasonable accuracy, but it would not measure small flows, and, moreover, the factor by which the reading of the by-pass meter must be multiplied to give the total flow was a varying quantity during the time that the check valve clapper was opening.

In searching for a remedy for these difficulties, we hit upon the idea of connecting in some way the action of the by-pass meter

with the raising of the check valve clapper, so that the multiplying factor would be automatically corrected, and thus give a true reading at all flows. The working out of this idea has proved to be *one* way of making a meter which can be safely used on fire mains, and which will measure small as well as large flows with sufficient accuracy for all practical purposes.

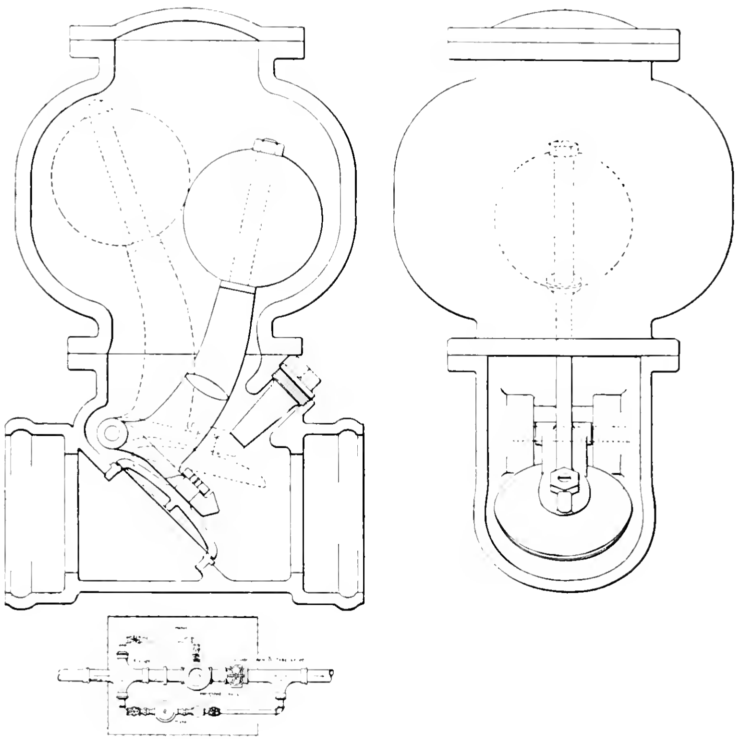

FIG. 1. WEIGHTED CHECK VALVE.

In seeking a method of taking care of the very small flows, we suggested in several instances putting a considerable weight on the clapper of an ordinary check valve, replacing the usual cover plate by a dome. Fig. 1 shows this idea. The thought was to so arrange the weight that it would exert a large force tending to hold the clapper on to its seat, but that as the clapper opened,

the weight tended to go toward the center, thus reducing the friction loss which the weight causes. This device would, of course, not measure the large flows at all, and would simply be useful as a means of getting at the small flows, but could, perhaps, be arranged with some simple seal or other indicating arrangement so that it would show whether the clapper had been off its seat or not. We suggested this in a few instances as a possible temporary expedient until a better device was available; but as we studied the problem it seemed to us (and the advice of several water-works men who have carefully considered this matter for years was in the same direction) that for the best results, taking it year in and year out, the ideal fire-service meter must be able to measure all flows,— the small as well as the large. We therefore set for ourselves the goal of getting a device which was truly a meter and which would reasonably record the smallest flows which any meter can detect, and equally well the largest flows which could be drawn through the fire-service connection.

After much designing, many experiments, and the discarding of ideas once promising, we built a 6-inch meter along the following lines:

First, there was a check valve of special design but of the usual type, except that all parts were made more substantial. The clapper of this check valve closed against a seat having an annular groove open to the atmosphere and giving a differential of about 6 per cent.; that is, the pressure on the down-stream side of the clapper must be about 6 per cent. lower than the pressure on the up-stream side before the clapper would open, this being due, of course, simply to the difference in areas on the two sides, the down-stream side having the greater area. A considerable weight was put on the clapper to insure its proper operation and to firmly force it on to its seat. Around this check valve a 3-inch by-pass with 3-inch disk meter was placed and a screen of large area, arranged to be washed clean by the current through the main channel, was provided; also a check valve in the 3-inch by-pass to prevent water going from the fire protection equipment back into the public mains. We then introduced a controlling valve, known as the "horn," which is attached to the check valve clapper, and which works in a hole through which the water from the

3-inch by-pass discharges on the down-stream side of the clapper. By experiment we filed this horn into such shape that it made the factor or coefficient, by which the reading of the meter must be multiplied to get the total flow, a constant for all rates of discharge. We found that this controlling horn would govern the water reliably and with sufficient closeness for ordinary practical work.

A measure of the small flows was obtained by holding the clapper of the check valve on to its seat by the differential action and by the weight until there was about 130 gallons flowing through the 3-inch by-pass, with which flow the loss of pressure through the by-pass was just about sufficient to cause the opening of the check. In this way, all flows up to about 130 gallons per minute were measured with all the accuracy of a 3-inch disk meter, which, it was believed, was sufficiently sensitive for any purpose.

It is desirable that one meter measure all the flows, and this was accomplished by letting the 3-inch meter measure the flows directly up to about 130 gallons, and then arranging a second dial which by a simple arrangement of levers was thrown into action the instant the main clapper opened. Having by the horn made the coefficient a constant for all flows, it was, of course, entirely possible to arrange the second dial so that it multiplied the readings of the 3-inch meter by the coefficient, thus letting the one 3-inch meter measure, first directly and second proportionately, all the water flowing. As worked out, the ratio between the main channel and the 3-inch by-pass is such that ten times as much water goes through the main channel as through the by-pass. The total quantity, therefore, is the sum of the readings of the two dials.

This first experimental meter, which may be seen at the left in Plate I, Fig. 1, was finished about January 15, 1905, and proved to us that this was one method, — not necessarily the only one and not necessarily the best one, but one way of metering a fire service. Feeling sure, therefore, that the main principles had been established, we redesigned the meter, with the idea of bringing it into compact and commercial form. The first meter had naturally been experimental, less compact than desirable, and many changes have been necessary as the experiments developed. The second

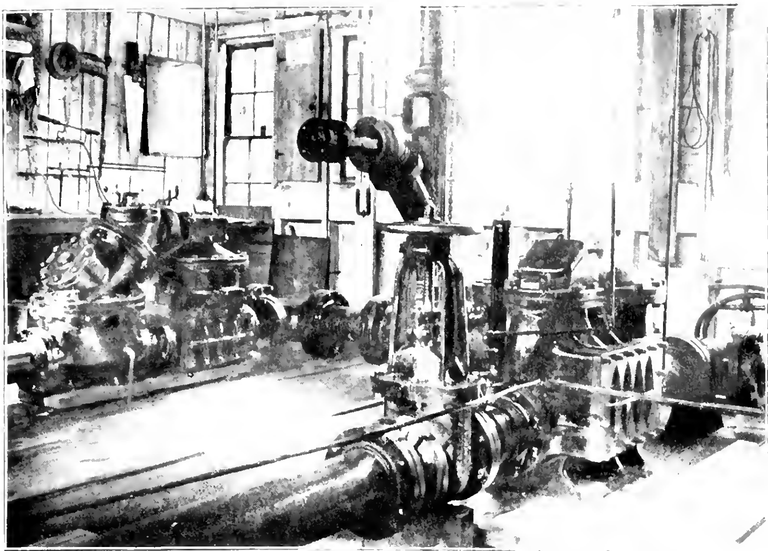

FIG. 1. FIRST AND SECOND MODELS OF PROPORTIONAL METER.

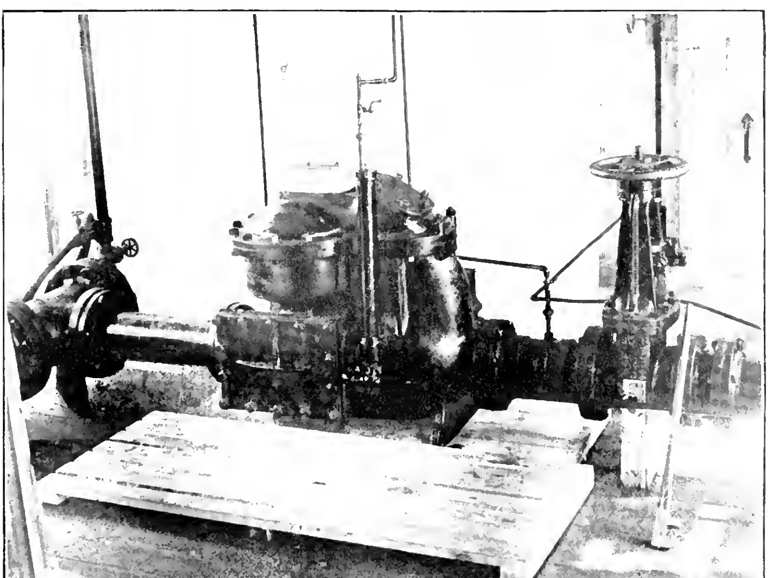

FIG. 2. SIX-INCH PROPORTIONAL METER.

meter, which is now completed, follows the same general lines but is in better form; an external view of it is shown in Plate I, Fig. 2, and also at the right in Plate I, Fig. 1, and a sectional elevation in Fig. 2. In this meter the clapper and attached parts are made heavy and the lead weight is about 48 pounds, so that a large and positive force is tending to hold the clapper

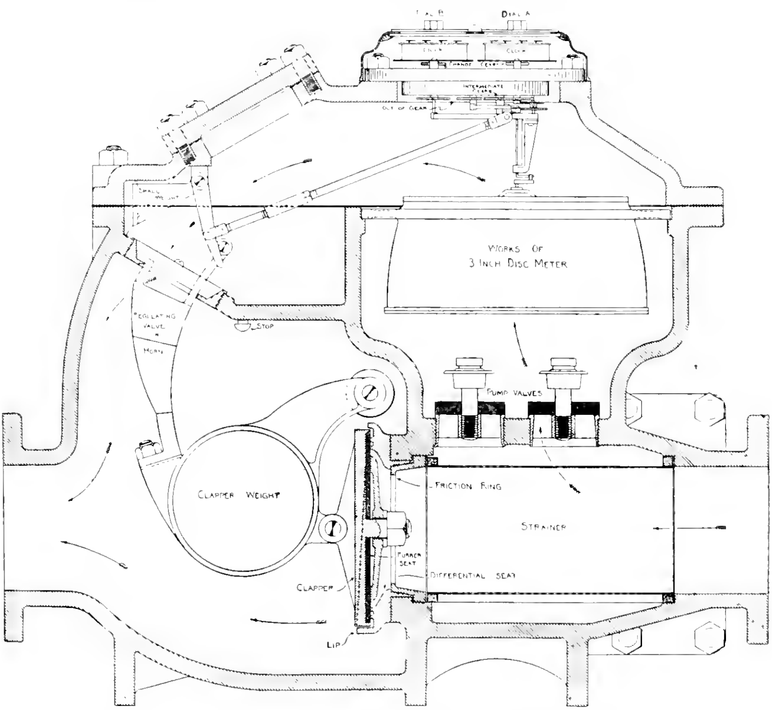

Fig. 2. Proportional Meter.

on to its seat. The annular space of the seat is open to the atmosphere and the differential action is less than 6 per cent.; that is, with a static pressure of 80 pounds the clapper would remain on its seat until the pressure on the fire-service side had dropped to about 75 pounds. It then leaves its seat with a jump, which jump is increased by the small lip surrounding the clapper, and this throws the horn into the discharge orifice from the by-pass.

and at the same time throws the second dial into gear, and the meter will register all flows proportionately from this point on. The horn corrects the coefficient while the clapper is opening, and experiments show that after the clapper reaches its stop, the coefficient is practically a constant for all further flows, at least within the ordinary range of commercial use.

After completing the first meter, shown at the left in Plate I, Fig. 1, we arranged it in the laboratory at Lowell in connection with the supply of the locks and canals, where, through the courtesy of the proprietors, excellent facilities are at our disposal for testing, so that the meter would get the almost exact conditions of actual use. To do this we allowed a small flow, 4 or 5 gallons a minute, to go through it for about two months, thus representing the possible small leakage of the ordinary fire system. Then about every week we ran through larger flows up to 1 000 or 1 500 gallons per minute, and at each time made a series of tests on the ratio of registration to flow when reading proportionately. The results from week to week varied slightly, but were all within reasonable limits, and are shown in the diagram, Fig. 3, thus indicating that the method of proportional reading was reasonably stable.

There has not been time since the second meter was completed to carry on a long series of tests, but with its better construction we have full confidence that it will give even better results.

We were troubled for a considerable time to get a satisfactory closing of the check, the tendency being not to re-seat until the flow was reduced to so small an amount that it could not be measured proportionately. After considerable study, we developed the idea of providing a ring around the seat about $\frac{1}{8}$-inch larger in diameter than the clapper, and then making the horn long enough so that when the clapper first jumps open it throws the horn a short distance into the orifice. The ring gives the clapper a larger opening at the start as the water forces it, the moment it leaves its seat, to the outer edge of the ring. The part of the horn thrown through the ring at the start keeps the proportional reading accurate down to the point where the clapper re-seats, which is, in the device as it stands, with about half the flow occurring at the opening point. As now arranged, the device will quite accu-

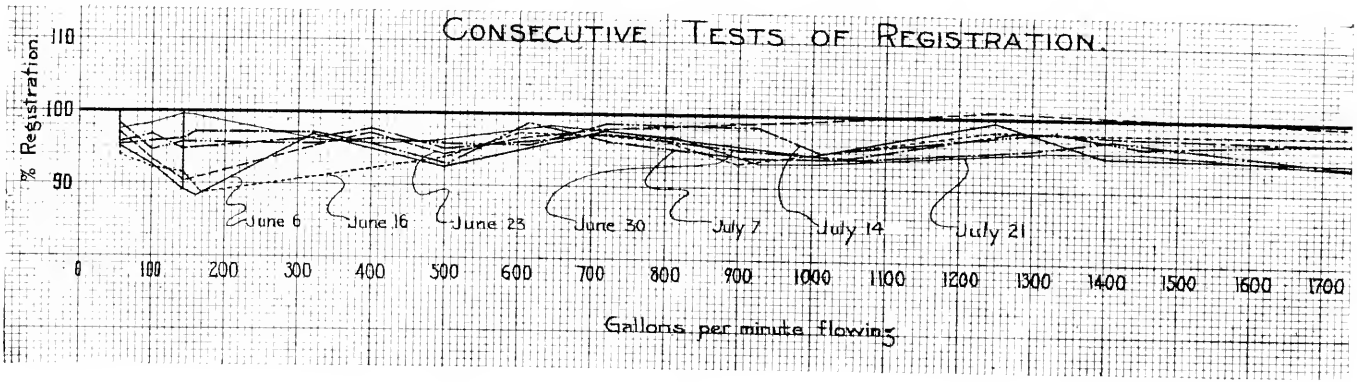
CONSECUTIVE TESTS OF REGISTRATION.
% Registration
110
100
90
June 6
June 16
June 23
June 30
July 7
July 14
July 21
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
Gallons per minute flowing

FIG. 3.

rately measure the water down to the closing point, thus covering all flows.

The device has the merit of requiring only one small meter for both small and large flows, and as the arrangement works, this meter is thoroughly washed out by a considerable flow going through it directly before it is called upon to measure water proportionately. This feature alone will be a considerable factor in insuring that any slight obstruction will be removed before the more delicate proportional reading commences. Again, with the two dials, a very good idea can be obtained as to the approximate rates of flow through the meter — a thing in some instances of value in controlling fire services. This is possible from the fact that the 3-inch meter measures on dial A the water coming through the by-pass, and on dial B the water coming through the main channel. If, therefore, for example, at the end of a month the total quantity is small and is all shown by dial A, it will indicate that all water going into the fire system went in at a low rate of flow. If, on the other hand, dial A shows but a small part and dial B most of the quantity, then it will indicate that the drafts were at a higher rate of flow. In the event of a fire on a service where the record on dial B was surely due to fire alone, — that is, there had been no other large drafts, — the water used during the fire would be the reading of dial B plus 1-10 of the reading, the tenth being simply due to the water which had gone through the 3-inch by-pass. In this way it would be very easy to deduct from the total flow for the month or quarter the amount which the fire caused and for which there would ordinarily be no charge.

The arrangement of the screen protecting the 3-inch meter is such that every large flow through the main channel would tend to wash off a considerable part of any accumulation, thus, in a way, making the thing self-cleaning. It is, of course, recognized that any large metering device must have some reasonable care, especially where poor waters are used, to be sure that it remains in working order. The whole thing has been designed in a simple and rugged manner, and with all parts readily accessible. The large weight, as suggested previously, insures the tight closing of the clapper under all ordinary conditions, while if any considera-

ble obstruction should get under it, the constant flowing of water from the annular space would at once give indication that the meter was out of order.

In the chart, Fig. 4, the lower curve shows the friction loss of the present meter (Fig. 2 and Plate 1, Fig. 2) as it stands to-day. We strove to keep the friction loss as small as possible but found a moderate loss necessary for the successful operation of the device. The meter has, however, one very good feature, in that the loss does not increase rapidly at the large flows, this being

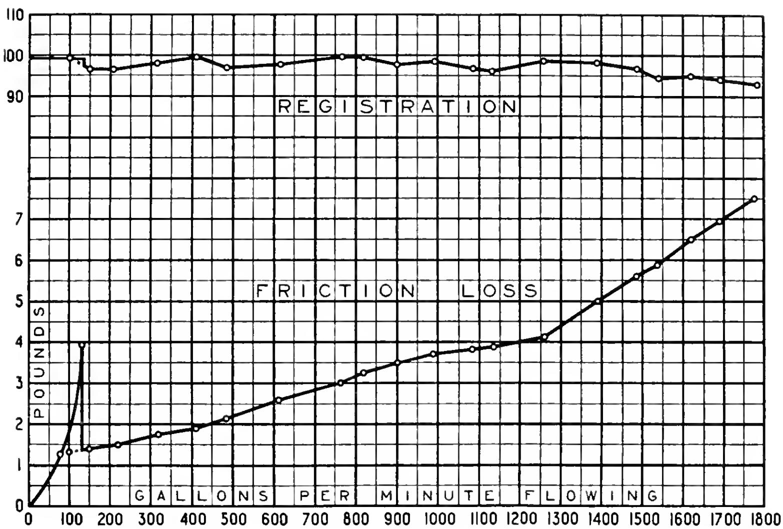

FIG. 4.

due to the fact that after the check valve reaches its stop, the loss is comparable with that of the ordinary check valve, the larger comparative loss at the lower flows being simply due to the weight.

The upper curve in Fig. 4 shows the degree of accuracy of the readings of the device, — at first when the by-pass meter is reading directly, and then when the whole device is working proportionately. The water in these tests was measured by nozzles in the usual manner. It will be seen that the registration, while

reading proportionately, is sufficiently close for all practical purposes.

Considering that this meter was mainly for fire services, through which there should normally be no draft, we have felt that the small waste from the differential space, which at 70 pounds pressure amounts to but 8 or 10 gallons per minute, was not objectionable. In a fire this small loss of water would not appreciably reduce the fire supply. Of course, with a meter of this kind there would be no serious objection to the occasional use of some water in a mill yard in an emergency, as in the case of the breaking down of a boiler feed pump, a condenser, or other similar use which in the past has given the water-works superintendent anxiety. Under such conditions there would be some waste from the annular space, but as these uses would be infrequent this waste would not seem objectionable. An arrangement has been devised for cutting this flow off when the meter is passing considerable quantities of water, but for the present it seems better to allow the waste, thus getting the full benefit of an immediate indication in case the check valve does not properly seat.

We have been pushing the development of this meter as rapidly as possible during the last few years, and those who have had experience in developing any device of this kind, or any general experimental work, will at once appreciate the many difficulties to be overcome and the considerable time necessary in getting a device into even reasonably complete form. It is our purpose to make this device available for any one for fire purposes in the near future.

We have watched with much interest the development of the Hersey Detector Meter. We have discussed the problem on many occasions with the manufacturers, have received useful suggestions from them, and have made available for common use some points brought out in our own experiments, for we have kept clearly in mind throughout all of this work that the chief aim was to get upon the market and have available for all a simple and reliable meter which could safely be used, and which would be acceptable to water departments on fire-service connections where some measuring or detecting device was imperative. The Hersey Detector seems to us to be available for many places and

is not objectionable from an insurance standpoint. It does measure the small flows and indicate reliably the large ones, giving a fairly good idea of the time in which large flows were going on. It further gives immediate notice whenever the clapper is off of its seat.

From a fire protection standpoint, it is in general objectionable to have water drawn from the fire pipes for manufacturing purposes. Such drafts, especially where considerable, mean that before fire pumps can produce a higher pressure for hose streams and sprinklers, it is necessary that they should discharge enough water to feed all the mill supply connections which may be open, and this often at a considerably higher pressure and consequently larger flow than when fed by city water. It is therefore our strong preference to have *fire pipes used only for fire purposes*, and under these conditions a meter which will measure small flows, thus recording the leaks in the system or any occasional small uses, and which will indicate the larger ones, would seem under many conditions to cover all the needs. We have, therefore, been advising the use of the Hersey Detector during the last few months, and in a similar way should be ready to recommend any equivalent device.

Our present position in regard to fire service where some improvement over existing conditions is desired is as follows:

(1) Ask the mill people to cut off every connection taking water for manufacturing purposes from the fire pipes.

(2) Put on a Hersey Detector Meter and have the mill people clearly understand that they must not draw water through the fire-service pipes, except in the case of fire and for such periodical testing as may be agreed upon with the water department.

(3) If the water department feel that a meter measuring all flows is necessary, we hope that the device which we have developed, and which has just been described, can soon be made available, and of course could be put on in any case where preferred.

We believe, therefore, that a distinct advance has been made, and that it is to-day feasible to put a guard over the fire service which with reasonable care will give the water department full knowledge of what is going on and full protection against any improper taking of water. It is, of course, recognized that a

meter such as we have attempted to develop, which will measure all flows, would be the best possible thing, in that it would leave no opportunity for dispute, for whenever a protected mill drew water through the fire pipes, either properly or improperly, the matter could be at once adjusted by the rendering of a bill with no argument as to why the water was drawn or as to the amount drawn.

It has occurred to us that to discourage any use of water through the fire system, except in emergencies, it would perhaps be proper to charge for water used in this way, except water used in actually extinguishing fire or any reasonable testing, a little higher rate than for water used through the ordinary mill-service meter.

The National Fire Protection Association, which to-day has representatives from all of the underwriting and most of the allied interests connected with fire-protection work, has appointed a special committee * to consider the whole private fire-service problem, thus showing that the underwriters and fire-protection engineers as a whole are quite alive to this matter, and are desirous of meeting it in a proper and comprehensive manner. This National Fire Protection Association Committee met a committee of the American Water Works Association in the spring and discussed various problems with them, all as shown in the transactions of the American Water Works Association and proceedings of the National Fire Protection Association.

At the joint meeting of the above committees the following resolution was adopted:

"That it is the sense of this conference that an apparatus embodying an indicating check valve which shall not afford an initial resistance greater than about 6 per cent. of the available pressure, with a metered by-pass, will prove acceptable on fire risks to both committees represented in this conference."

* This committee consists of —

E. V. French, chairman, Associated Factory Mutual Fire Insurance Companies, Boston.

A. Blauvelt, associated manager, Western Factory Insurance Association, Chicago.

J. E. Diebold, inspector, Burrows, Marsh & McLennan, Chicago.

H. A. Fiske, manager, Special Risk Dept., Phœnix Insurance Company, Hartford.

C. B. MacKinney, care Starkweather & Shepley, Providence.

H. L. Phillips, manager, Factory Insurance Association, Hartford.

A. R. Williams, special agent, Union Assurance Society of London, Milwaukee.

This resolution was ratified by the full convention of the American Water Works Association at West Baden, and also at the ninth annual meeting of the National Fire Protection Association held in New York.

It is the desire of the committee to discuss these matters in a friendly way with water-works men, and it is believed that we need the advice and counsel of those practically engaged in handling water supplies to wisely settle the various problems which arise in connection with fire services. This committee is therefore ready to discuss with the committee of this association any problems of this kind at any time, and we believe that there are no difficulties which cannot in this way be satisfactorily overcome.

In closing I desire to make it very clear that the meter which has been developed is the product of our Inspection Department and that valuable ideas have been received from many members of the department, and especially from the following men: Mr. Ezra E. Clark, starting with the idea that there must be a connecting link between the clapper opening and discharge from the by-pass connection, suggested and developed the horn regulating valve and the one-meter idea and worked out the original studies leading to the putting of the whole device together in compact and practical form. Mr. George F. Hiller worked out many important points and designed and built the first meter, and carried through with much patient work the experiments necessary to bring it all into its final perfected shape. Mr. Edw. W. Sibley laid out the main lines of the second meter in its present commercial form, carried it through the shops with much energy, and has given many long days to putting the meter in its present completed form. Messrs. Clark and Hiller have followed the later developments, giving valuable suggestions and advice at various times, so that the whole thing is an excellent example of the advantage of the free coöperation of several men interested in the same problem but getting at it from different directions and with different experiences.

DISCUSSION.

MR. EDWARD W. BEMIS.* I should like to ask Mr. French a question bearing on our experience at Cleveland with the Hersey Detector Meter, which we tried as an experiment. We found with the meter which we placed in the basement of our City Hall, that there was a great deal of water-hammer owing to the elevators in the neighborhood, and this caused a fluctuation much greater than the 6 per cent. It caused the very frequent opening of this clapper and a considerable loss of water through the annular opening every time this occurred. This was such a serious matter that it discouraged us for the time being in the use of the meter; of course we may return to it. I should like to ask Mr. French if he has solved the problem, and how much water is lost — I think he told us but I didn't quite grasp it — in such a case as that, and what he would do where there is considerable water-hammer through elevators, etc.

MR. FRENCH. Our feeling is that perhaps that is somewhat an abnormal or rather an unusually serious condition, and that it would be rather desirable to find a remedy for the water-hammer, for it is pretty likely if it doesn't hurt somebody's meter that it will hurt something else. The amount of water escaping — the orifice would be somewhere between one eighth and one fourth of an inch — would be somewhere between 5 and 10 gallons a minute with a static pressure of 70 pounds. If the water-hammer was simply a momentary jump, I should expect that there would be very little water lost. If it was of a longer surge type the clapper might stay open for half a minute, and perhaps there would be a loss of 2, 3, 4 or 5 gallons every time. We haven't given special consideration to getting over that difficulty, feeling that in the average service such as we are connected with, and where we would ordinarily be at the entrance to a mill yard with considerable pipe beyond us, that would not be a serious matter.

MR. BEMIS. Suppose there was an hydraulic elevator in the mill, would there not be that water-hammer?

MR. FRENCH. There might be that water-hammer and it might occasion some trouble such as you mention. I should think

* Superintendent of Water Works, Cleveland, Ohio.

that in a case like that the placing somewhere of a fairly good sized air chamber would perhaps cover the difficulty. I think it would have to be treated somewhat as a special difficulty in each case, depending on the local conditions.

MR. FRANK C. KIMBALL.* At Mr. French's invitation, and in company with two members of this Association's Committee on Private Fire Services, I had the pleasure of inspecting this meter at Lowell last Saturday. Our time was so limited that we could make no special tests of it, but the tests that had been made I was somewhat familiar with from the fact of having made numerous tests along these lines myself, and I was thoroughly satisfied that the meter would do all that is claimed for it. It seems to me that Mr. French has come nearer hitting what is required along these lines than has been accomplished heretofore. He certainly has a meter which is acceptable to the insurance people, and that is saying a great deal.

Just what the unforeseen is that will happen to this meter, which question has always troubled Mr. French and the other insurance people, I don't know. We will leave them to work that out. From a water-works standpoint, and speaking as one who, perhaps, has looked into this question of metering fire supplies as much as any one, I would express the opinion that this fully meets our desires. As we all know who have used them, any of the present 3-inch disk meters will measure streams, even very small flows, fine enough to satisfy even a hypercritical water-works man: and with this device arranged as it is, so that it measures even at the highest flows within 5 per cent., and, as Mr. French has very plainly shown, can be made to register undoubtedly even closer than that if the game is worth the candle — which I do not think it is — I believe that water-works officials have something so good that they cannot reasonably ask for anything better. This is all on the supposition, which I think is a correct one, that there are no mechanical difficulties in the way of building this apparatus.

I am sure that so far as the companies that I represent are concerned, where I have for some years, as Mr. French very well knows, taken the stand that some device must be used to deter-

* Civil Engineer, Boston, Mass.

mine whether or not water is used properly or not used at all, as they claim frequently is the fact, we are ready to accept the situation and go in with the underwriters on this device, as in fact we have already in one or two instances with the Tilden-Hersey device.

There is one point that Mr. French made as regards not using any water even with this device upon sprinklered mill services, with which we somewhat disagree. We have felt always from a water-works standpoint that some water used through a fire service which was metered was of advantage because it showed whether or not the apparatus was in working order and would respond when it was necessary to call upon it. Of course that is a matter which perhaps is not of serious consequence. If they can induce their mills to put in two connections or three or four in place of one, water departments as a rule, I think, would have no objection. If we should attempt to carry out the suggestion, however, to discourage the use of water through fire-protection fixtures for other than fire purposes by charging a higher rate for water used through such fixtures, I think some of our legal friends would come forward with decided objections which would prevent water departments from so doing.

I am very glad indeed to see the result of what has been done by the underwriters' association that Mr. French represents. Those of you who have heard him discuss this question before undoubtedly recall his remarks as to the device that he was perfecting or getting ready, and I am free to say that some of us, and I was one of them, thought that it was only to stave off the evil day when meters were coming. But I am very glad to find that I was mistaken, and that he has brought out a device that I think we can all adopt. I think we may feel confident that this whole evil of stealing water will be brought very close to an end, at least where politics do not interfere to prevent. Not only are the Factory Mutual companies entitled to a large amount of credit for this, but I think that this association, and as well the American Water Works Association, can take a good deal of credit to themselves for forcing the companies to produce something to accomplish the end for which we have been seeking. If we had kept quiet and waited for Mr. French to have developed

this in his own good time, it might not have been developed within the next — well, six or eight months at least.

THE PRESIDENT. We should like to hear from Mr. Tilden.

MR. J. A. TILDEN.* Mr. President, I did not expect to have anything to say to-day, particularly as, being an associate, I have no claim on your time. I should like, however, if you please, to correct, not what Professor Bemis has said, but to correct an erroneous impression which I fear has been derived from what he did say. The Hersey Detector Meter to which he referred was not of the commercial form. Professor Bemis up to the present time has never had nor seen, except in the exhibition room here, a commercial form of the Hersey Detector Meter. What we did do was to send to him at his request what we then had on hand, which was a detector meter in the process of development. This meter is fully explained in Mr. Sullivan's paper (printed in this issue of the Journal), and which you will notice is there marked "4-inch swing-check device (experimental)." That is the one which Professor Bemis had, a style which has been entirely abandoned. It was one of the earlier experiments.

I think I risk little in saying that in all the series of experiments at Lowell, extending over many months, and that in all the record of use,— and I can see gentlemen here who have these meters in actual service under most severe water-hammer,— no one has ever known of such a thing or heard of such a thing as the check unseating from water-hammer. The detector which Professor Bemis had was not set on a service leading to the building. It was set on a pipe leading off the service and passing to a dead end, where if there was any disturbance at all it would be felt in intensified form: and, as I have before said, that detector was simply put out as an experimental device; it was not of the present commercial form.

I do not know what I am expected to say on the general subject. There has been, as you know, a very earnest effort toward the development of some kind of a metering device which will, as far as practicable, meet the requirements of the underwriter and of the water-works man. The requirements are very, very severe. The underwriters on the one hand say that you must not put

* Mechanical Engineer, Hersey Manufacturing Company, Boston.

anything on the main fire line which will in any degree obstruct or endanger the flow. They take the stand of absolutely prohibiting, that is, so far as lies in their power,— and the power of raising insurance rates is something tremendous, — anything in the shape of a positive meter, either piston or rotary. The current meter is to-day — well, we will say tolerated — tolerated, that is, by the underwriter. The current meter being of the water-wheel type of course is less liable to obstruction, but all the commercial forms are provided with a screen, and the underwriter has holy horrors at the idea of a screen on the fire line; because in the first heavy draft incident to a fire there will pass from the mains large accumulations of sediment, scale, grass, and all kinds of things which are, but which ought not to be, found in good water supplies.

So, therefore, in the attempt to work out this problem we went to the underwriters, and we said, "What will you allow? We have got to have something on that pipe in order to approximate some kind of measurement, in order to undertake to do anything in the way of measuring water." After it was all boiled down it seemed that about the only thing that would be permissible would be a self-acting swing check-valve, just such as Mr. French uses in his meter and just such as is used in the Hersey Detector Meter. Now, with only that on the fire line the question of obstruction seems to be settled, that is, so far as the underwriters are concerned.

Then comes the other side of it — what does the water-works man want? He wants to measure all flows down to a gallon or two a minute, and everything over that clear up to the highest rate. Bearing in mind the fact that fire supplies are generally and should always be — so our underwriting friends tell us and so our water-works friends agree — used for fire protection only; bearing in mind that water if used at all for other purposes on those lines is used illegitimately, and bearing in mind also the fact that all men are not thieves, that there are not 10 per cent. of them who are, — not one per cent. we hope, — there is a very small percentage who do, we are forced to admit, deliberately take water. Thus, there is a very large percentage of fire services which, if supplied with something in the shape of a detecting

device, would seem to meet the requirements of the water-works man. Hence the development of the detector meter, which is a device which will measure all flows, from 1 up to 150 gallons a minute, and which, when there is a call for a sudden draft for fire or other emergency, will open wide and give unrestricted flow.

Now Mr. French and his associates, with infinite patience and skill, have gone still further than we have. Our device and the device of which Mr. French has spoken are parallel up to a certain point. Both have the weighted differential check-valve, and both have the by-pass meter; but in the latter device they go further than we do. While we measure simply the water passing through the by-pass, they measure all the water. If as a matter of record it is desired to parallel the description of the French device with a description of ours, I will, if you please, submit Mr. French's report on the Hersey Detector Meter, as prepared by him as chairman of the Private Fire Service Committee of the National Fire Protection Association, and which he presented to the association, and which is printed in the 1905 transactions, as a part of my remarks, giving as it does a description in Mr. French's own language of the Hersey Detector Meter.

This device is called the "Hersey Detector Meter." Its object is to measure accurately drafts up to about one hundred and fifty gallons per minute, and to detect and exhibit the flow of any additional quantity in excess of the above amount.

The device consists of an indicating check-valve in the fire-service main and a meter on a by-pass around it. There is no mechanism in the main pipe except the check-valve, which offers no objectionable resistance, and gives a practically unrestricted waterway for use in case of fire.

What the detector does, is, first to cause all drafts up to about one hundred an dfifty gallons per minute to go around through the by-pass meter, where they are all measured; second, to give a positive indication that while this is going on the check is closed; third, to give a positive indication if the draft exceeds 150 gallons per minute, and about how many hours such an excess has been going on and, if desired, to indicate about when it took place.

The device is furnished completely assembled so that it may be set as one piece in the main pipe line. It may be assembled so that the by-pass will be on either side of the main fire line, or on top or underneath if more convenient. The by-pass is controlled by valves so as to permit inspection of the meter without

closing the fire line. In case it is desired to use the whole device in place of the main yard check, the valve on the mill side can be a check-valve.

The main check-valve is provided with a differential seat which, with the by-pass, gives an initial resistance of about 6 per cent. of the available pressure. When the by-pass meter is delivering about one hundred and fifty gallons per minute, the friction loss through the meter reduces the back pressure on the check to the equalizing point, and any draft in excess of 150 gallons per minute unseats the check and finds unrestricted passage through it.

The moment the check leaves its seat a small amount of water flows from the differential seat to the atmosphere through the small indicating meter, and this meter will continue to run as long as the check is off the seat.

The check is so weighted that it will close when the flow drops somewhat below the flow which caused it to open.

The device will, therefore, accurately measure all leaks or ordinary small drafts, will give unrestricted water-way for use in case of fire, and will detect and show if water has been used in very large quantities, giving an approximate idea of the length of such use, and of about when such drafts occurred.

Mr. French. Mr. President, if I may take one more minute I want first to pay my compliments to Mr. Kimball. Mr. Kimball has been possibly one of the great spurs to our activity in this matter, because he desired to measure every bit of water down to a single drop, and when he stood at Lowell last Saturday and looked down on that meter and said that he felt that it would really do the work, it was the top notch of commendation. Nothing more can be said.

Now, there is one thing which would be of a good deal of interest to us. I should say, looking at it broadly and putting aside our own pride, which in the insurance business we generally put one side, that we should like very much to know the general feeling of water-works men as to the need of a meter to measure all flows. This meter of ours might in a way be designated as the "all-flow meter," or some such thing as that, — we are trying to think of a good name for it, — and our feeling is this: that a simple "detector device" would be from our standpoint, perhaps, less objectionable on the fire service than this which has something more to it. That is, we don't want anything, and the less we

have of something the better we will like it. That is putting aside our own development, which, of course, in a way we are quite proud of. And I should like to know whether in the judgment of water-works men a simple detector device which would measure all flows up to say 150 gallons a minute, and which after that would merely indicate that there had been large flows, doing simply what the Hersey Detector does — whether that would not in a great many cases be all that was necessary. And if it would be all that is necessary it certainly is the simplest thing. We have discussed that among ourselves, and we simply stuck to our goal. We started in with the idea of making a meter which would measure everything, and we thought we wouldn't stop until we got there; but that does not mean that in practical use something even less extensive might not be just as good and, being simpler, perhaps better. It would be quite interesting to us to know the general feeling on that line.

MR. GEORGE A. STACY.* We haven't as yet had any of these troubles in Marlboro. Of course we are interested in this matter, however, for we don't know how soon it may be up to us. All of our factories have sprinkler systems, and some of them have three and some have four connections, and I can say that up to the present time we do not know of a single instance where any water has been stolen from us. There has been only one instance during an experience of twenty-two or twenty-three years when we have had any suspicion that water was being stolen.

THE PRESIDENT. We should like to hear from Mr. Nash.

MR. LEWIS H. NASH.† I do not feel that I can add anything to the discussion, for the reason that I came into this matter a little late. I think some of our friends had been working on this problem a year or two before it presented itself to me as one which needed attention. Some years ago, however, I made some experiments in proportional meters, and during that time I went over ground very similar to this. In fact I made use of a great number of different methods of obtaining proportional measures, and in one of those devices a weighted valve was used, which weighted valve was governed by the flow of the water, and the

* Superintendent of Water Works, Marlboro, Mass.
† Mechanical Engineer, National Meter Company.

device was expected to register upon a drum so as to give the amount of water in proportion to the opening of the valve. That was a good many years ago and the thing was laid on the shelf then because at that time I did not think it was a device which was needed. But there was enough done by me at that time to make me certain that something in this line will be successful, and as I listened to Mr. French's paper it seemed to me that he has come to the best solution which has been brought forward, so far as I know.

Of course the success of the device will depend very largely upon how the mechanism is constructed and how durable it would be, and upon points like that, which nothing but experience can determine. As I understand the problem, the intention of the insurance people was first to stimulate the thought of those who are manufacturing meters, to see if something could not be produced which would be satisfactory to them, and they having failed in the first place to exhibit that interest, the insurance people have taken up the problem themselves, and I think they are to be congratulated upon their success, so far as it has been shown here to-day. I suppose perhaps some of us meter people will now "get a move on."

MR. ROBERT J. THOMAS.* Mr. President, it seems to me that both the detector and the meter which Mr. French has described will have their place in the metering of fire services. In a great many cases the detector will answer the purpose perfectly, and in other cases it will be necessary to have all the water supplied through a fire service metered. This matter of metering fire services has been agitated, as you know, for two or three years, and was referred to a committee, of which I am a member, and we have made two or three reports. To-day, owing to the absence of Mr. Crandall, the chairman of the committee, we haven't any written report to make. The work of the committee has been fruitful; there is no question about that. The results are known to those of the members who have kept in touch with this matter. I think the paper of Mr. French is an indication of the good work that was started by this Association and carried along to a great extent by your committee. The paper read by Mr. Sullivan last

* Superintendent of Water Works, Lowell, Mass.

March, and the paper read previously by Mr. Kimball were indirectly the result of the work of the committee. That is to say, Mr. Kimball, representing General Wheeler of the committee, made the tests at Knoxville of meters for fire services. Mr. Sullivan at Lowell, representing myself and the members of the Lowell Water Board who were interested in this matter, made the tests in Lowell in order to find out the best type of machine or device for measuring fire services.

The fact that water supplied through fire services should be metered was recognized, I suppose, by all the members. In our previous discussions of the subject in this Association there was hardly a dissenting voice as to the necessity and the importance of a water-works department knowing the amount of water which was being used by factories and power stations and various establishments which were supplied by pipes 6, 8, 10, and 12 inches in diameter. It has been well recognized that there is, to say the least, a great waste of water, a great waste of a valuable commodity, which water becomes, especially when it is pumped, through these fire services.

It appears now that Mr. French is just as ardent a supporter of metering fire services to-day as any water-works man, and for the reason that he believes it is for the interests of the insurance people to have them metered. You notice what he said about the importance of having the fire service used exclusively for fire purposes. He told you of an instance where they were using water for other than fire purposes and they were able to get only two fire streams at the time of a fire when they should have had four streams. That, of course, is a very important matter in the estimation of the insurance men, and of water-works men also, for we all agree that a fire service, intended for the extinguishment of fire, should be as complete and perfect as possible and ready whenever it is needed. The use of water for other than fire purposes interferes with the efficiency of the fire services, and it may practically destroy it at the time of the greatest need. Now, if you put a meter on the service and measure the water and make a concern which is using the water illegitimately pay for it, the chances are that they will not use it to the extent that they have been. They certainly will not use it to the extent that they

do when they get it for nothing, as they are in a great many cases from probably every water-works department in the country that is supplying large fire pipe lines.

The American Water Works Association has taken about the same position that the New England Water Works Association has on this matter, and has voted in favor of meters. The committee of the American Water Works Association has come to the same conclusion that your committee has, and there seems to be quite a unanimity of feeling that fire services should be metered, either by meters measuring all the water flowing through them, or by detectors which will detect the fact that a concern which is given the privilege of a fire service is abusing it, and then the city department or the water company can reckon with them and make them pay for the water used, or else make arrangements so that it will be impossible for the water to be used in the future.

Another matter with regard to fire services. It is well understood, of course, that the city is willing at all times (and the private water companies, too), to go to quite an expense to put pipe into the different mill yards, and not only into mill yards, for we have breweries supplied with fire services as well as cotton mills and woolen mills and wood-working establishments. All kinds of property are supplied with fire services, so this is not intended to apply to any particular industry; they all need water, and you will find that they all use it, particularly if they can without paying for it. Now, as I say, the city is at all times ready to furnish a supply of water for the purpose of extinguishing fires; but at the same time the laying of large mains into private concerns is a privilege they are getting from the city, and that privilege should not be abused.

Now, if there is some safeguard, such as the meter Mr. French has told us about, or the Hersey Detector, or some other device, why should it not be put upon the fire services to prevent their abuse, and to give the water department the knowledge which they have in every other case? As a rule now the custom is not to supply water to a private dwelling without a meter, and if we are so careful in regard to supplying private houses, tenement property, etc., with water, to know where the water goes and to put a meter on, we certainly should be just as careful to ascertain what

becomes of the water and how much of it is used, which goes through a 6-, 8-, 10-, or 12-inch pipe. The size of the main should not be an argument against putting on a meter.

We have a large concern in Lowell which had three fire services put into their premises, two 8-inch and one 6-inch, and they had probably thousands of feet of pipe laid through their yard. They wanted another service put in; the water board told them that in order to have that other fire service they would have to have all their services metered. They looked up the price of meters and found it would cost about two thousand dollars, and the agent of the concern said, "That is quite a bill for us to pay, and quite a hardship." I thought so myself, and so did the board, but they had to begin somewhere and here was an opportunity, and they said, "You shall not have this extra supply of water unless you meter the others."

They were insured with the Factory Mutuals; and by the way, the Factory Mutuals, as we all understand, are one of the greatest insurance organizations in this country, and when a representative of that company advocates meters it means a good deal. They consulted the Factory Mutuals, and in a short time I heard from Mr. French. He said, "The Lowell Bleachery telephoned to me with regard to having some meters put on." I told him the exact condition of affairs and he said he would recommend that the concern discontinue one of the services and meter the two 8-inch services, and also that the new service, which was to supply a cistern, should be metered. And the company, I am pleased to say, shortly afterwards made an application for the meters, one on the new service, and two 8-inch detector meters. We have metered quite a number within the last couple of weeks and expect to continue the work. It seems now if any water-works superintendent thinks his city or company is being robbed, or that there is a great waste of water — I won't say they all steal the water, for we find in a number of cases the owners of the property don't know that the water is being used, but some subordinate finds it to his advantage to use it and uses it without consulting the owner — there is nothing to hinder him from putting on a meter. The owner of the concern cannot go back to the old argument that the insurance company won't allow it.

Mr. French. I should like to make it very clear that the two meters which were put on in Lowell were the detector type of meters. That was the one restriction we made, and it was a restriction which Mr. Thomas and the water board were very willing to agree to. Mr. Thomas stated that, but I should like to make it a little clearer. We really haven't quite come to the position yet where we are advocating putting meters on every fire service, although we have come a long way, perhaps, from where we used to be. I think our feeling is this: that certainly our own device, and I think I may say the Hersey device, which happens to be the only one now available, both yet lack long experience. My own feeling is that there are a good many small and simple fire services which can be trusted to-day, and that it would be prudent and reasonable on the part of all of us not to insist on metering right away everything that we can see. We will not object to metering fire services in places where it seems necessary with some devices of this kind, but we should like to have the work go on slowly enough so that we might find out any little difficulties which experience almost always develops in the working of even the best thought-out device. We should like to get a little of that experience before we have a very large number of them in use. Of course in a year we will get a good deal of experience. I mention this for the reason that I believe that there are a great many small plants and some larger ones having new equipments that are perfectly simple, where perhaps it is not necessary to clap on a meter immediately. I think it would perhaps be only reasonably conservative to take the few worst places in any district until we get a bit of experience, and then we may perhaps hereafter be willing to go as much further as is necessary.

Mr. Bemis. Where cities are putting meters on at the expense of the department but haven't metered the fire services, I suppose Mr. French has no objection to our requiring the consumer, in the case of fire services at least, to pay for a detector meter or for his meter?

Mr. French. We really do not care who pays for it. That is purely a question of practice in the city. Some cities buy the meters, I believe, and others make the consumer pay for them. It is quite immaterial, of course, from our standpoint.

MR. F. A. W. DAVIS.* Mr. President, I am heartily in favor of any device which will prevent water being used surreptitiously in a factory; but there is one feature of this whole subject which should not be overlooked by the water departments. The requirements of the insurance companies are for larger mains, increasing the size constantly. Now, can the departments afford to do that? I do not mean in the way of furnishing a water supply, but can they afford to jeopardize the balance of their systems and their obligations to the public at large? And when they put a main into a factory, which in the event of a fire may be broken and destroy the pressure in the neighborhood, that should be considered in talking about furnishing inside fire protection. Mr. Kimball has had some experience on that line, and I have known a number of cases where the pressure has been so reduced by a broken pipe as to make the department almost helpless.

MR. FRENCH. Mr. Davis has struck on a very vital point for the water department and for the protected risk, and I want to mention one or two things which in a way are on the other side. First, I should like to say this: That I believe that any fire protection engineer who is true to his calling will never put a pipe into a building the breaking of which would cripple the fire service. It is one of the cardinal principles of fire protection engineering that every large pipe going into a building shall have a properly located outside shut-off. In our own work, where we are dealing largely and almost entirely with mill yards, we usually provide a gate in the yard with an indicator post standing up above the snow line and very accessible. We have done that for years for our own protection. In the early days we had several mills burn, and the breaking of the pipe destroyed the protection of the rest of the yard. Those were mills in the country and they were dependent on their own supply for protection. But it is just as necessary to avoid that danger in the city as it is in the country, and we invariably put not only a gate on the service from the city, but a gate on every connection going into every building, and we locate that gate outside of the building in such a position that we believe it will always be accessible even if the building which the supply protects is on fire.

* President, Indianapolis Water Company, Indianapolis, Ind.

The next point is this: That in a city (I think a careful study of the records will prove this absolutely) the risk that is sprinklered is the one which is least likely to cause a bad fire, or to cause the start of a bad fire. At Baltimore I have no hesitation in saying that had the risk in which the fire started been sprinklered the Baltimore conflagration would not have occurred. As it was, the fire came up to two large sprinklered buildings, which were insured in some of the mutual companies, and the sprinklers in those buildings stopped the fire, so that those buildings marked the boundary line of the fire in their direction. At Toronto the same thing occurred. The fire came up to one building and got into it. The water supply was pretty good but it was not sufficient to check the effect of the terrific heat, and the roof was burned off; but the operation of the sprinklers introduced the element of delay at that point which enabled the fire department to check the fire there. So it seems to be true that while the private fire service does put a large pipe into a building, it at the same time immensely reduces the chance of a fire in that building assuming dangerous proportions; and, furthermore, it makes the building a strong barrier against even a conflagration which is coming toward it.

Looking at the thing broadly, and understanding that the water-works man feels it is his duty to prevent fires, there is no better way of doing this than by equipping buildings with automatic sprinklers, and to be serviceable they must have a large water supply at a reasonably good pressure. So we must remembe· that while we possibly introduce a danger when we sprinkle a building and carry a large pipe into it, we on the other hand very much reduce the chance of a bad fire. And I think there can be little doubt in the minds of those who study the action of sprinklers, that if all the buildings in a city were sprinklered the conflagration hazard would be absolutely eliminated. That is the position practically of underwaiters of all kinds whether of stock or mutual companies.

There is yet another point to be considered here. I suspect that in many cases the connections which have broken and made trouble have been elevator connections or something of that kind, and I think it is quite as necessary for the water-works

engineer to give careful attention to all of his large services as it is to single out those intended solely for fire protection.

Mr. Morris R. Sherrerd.* What Mr. French has just said may perhaps be true from the point of view of the Factory Mutuals, but I want to add a word in support of the position Mr. Davis has taken. I find that many of the insurance people are very unreasonable about the size of the fire connection they request the property-owners to provide. Invariably they want it as large as the size of the main in the street, up to twelve inches. If there is a twelve-inch main in the street they will ask the proprietor of a large department store, for instance, to install a twelve-inch pipe. We have adopted a rule in Newark to lay from our high-pressure fire system nothing larger than six-inch connections. If the owner of a large building wants to put in a sprinkler system and the insurance people require a greater supply than a six-inch, we will allow another six-inch connection which shall be located in a different part of the building, so that in case a fire gets beyond control, a falling wall would not be likely to break both connections and thereby seriously affect the general protection. Of course I can appreciate that it is of advantage to the city to have these large buildings properly protected by sprinklers, but some of the representatives of the insurance companies, I am sorry to say, impress me as only considering the particular risk upon which they are working, and arbitrarily demand as large a connection, even from high-pressure lines, as was formerly requested from the regular service.

Mr. W. C. Hawley.† Answering the inquiry which Mr. French made regarding the matter of preference between these two devices which are before us, personally I cannot see very much to be gained by a device which measures all flows of water unless in cases where water which may be used in a fire is paid for on the basis of the quantity used. The other device measures what is wasted or what is stolen, and it seems to me that that is the important thing for us to know.

The report of the committee this morning regarding the method of charging for metered water, and the point that we have reached

* Chief Engineer, Water Department, Newark, N. J.

† General Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

in this discussion, brings a matter to the attention of this Association which should be taken up, and that is the proper basis on which to estimate the value of fire protection to manufacturing or other concerns that have special protection. At present there are various ways of measuring it. Sometimes it is to count the number of hydrants and the number of sprinkler heads and charge so much for each; sometimes it is simply a flat rate, without any particular method of getting at it. If we could get as satisfactory a solution of it as has been presented by the committee of the problem of meter rates, it would be an excellent thing for all who have this subject confronting them. I would move, therefore, that a committee of five be appointed to consider this matter and report at some future meeting of the Association.

Mr. Sherman. If I am not laboring under a misapprehension, Mr. President, that very subject is among those referred to our present committee on fire services, which was scheduled to report to-day, but which, as Mr. Thomas has told us, will be unable to report on account of the absence of the chairman, Mr. Crandall.

Mr. T. H. McKenzie. I certainly approve of Mr. Hawley's motion. It seems to me the old committee is rather avoiding the main question of recommending rates for fire services. They get off on to other subjects and do not quite come to the point of recommending rates for sprinklers and hydrants and other methods of fire protection.

Mr. Hawley. When I brought up this matter I did not know that it was being considered by any committee. If that is the case I will withdraw my motion, but I certainly think this is a matter which should be given attention, and that the Association in the discussion of this general subject has now reached a point where this specific matter should be taken up. I will make the motion that the committee consider and report a method or methods by which the value of fire protection can be estimated.

Mr. Hugh McLean.* In our city we find them coming out into the mill yards and putting their fire hose on to the hydrants. In New England cities like Holyoke, and other cities where they use water for power a great deal of the time, when the water-power plant is shut down they find it convenient to attach the hose to

* Member Water Board, Holyoke, Mass.

the city supply to get water to wash up with, and there is a great deal of water used in that way. We have been trying hard to get at some method of putting a meter on the fire service so as to stop that. Our ordinary consumption is from 70 to 75 gallons per capita between the hours of one and five in the morning. We sent men to go through the mills, and the owners put them out or wouldn't let them go through. Then we got an opinion from the city solicitor which forced them to allow the inspectors to go through. I want to say in behalf of the manufacturers that I do not think they themselves are responsible. We have had letters of apology from the leading mill superintendents. But it is certainly very convenient for the employees to use the water. I know when I was a boy and worked in a paper mill it used to be very convenient for me to get hold of a hose and wash down the screens and the wires and do the general cleaning up, and it is a habit now, and we want to find out some way of stopping it. Applying a meter on all fire-service connections in mills will do it. So if it is possible for this Association to go on record in favor of a meter which can be immediately applied, we would like to take advantage of it.

Mr. Hawley's motion was adopted.

MR. STACY. I consider this last question which has been before us, and which, as I understand, has been referred to the committee, a very vital one. It is something which has been before the Association for quite a while. I do not know of anything that this Association has ever taken up that it has not carried through, as is illustrated by the matter of the metering of fire services which our committee has very efficiently forced to an issue, in one sense of the word. And now I would move that, in order to strengthen the committee still further, Mr. Batchelder of Worcester, water commissioner, be added to it, for he is a man who has had a good deal of experience along this line.

THE PRESIDENT. That would make a committee of four; shouldn't there be five?

MR. STACY. I would suggest that Mr. McLean of Holyoke also be added.

It was voted that Mr. George W. Batchelder and Mr. Hugh McLean be added to the committee.

REPORT OF THE COMMITTEE ON METER RATES.

FREEMAN C. COFFIN, CALEB MILLS SAVILLE, HENRY V. MACKSEY, FRANK E. MERRILL, CHARLES F. KNOWLTON, *Committee.*

[*Report presented September 13, 1905.*]

To the New England Water Works Association:

There are indications that a point has now been reached in the history of water meters from which there will be a greatly accelerated increase in their use. The fact is undoubtedly established in the minds of water-works men that the general use of meters prevents most, if not all, of the waste of water in the houses of consumers, and that it does not restrict a liberal use of water for all legitimate purposes. There is still, however, an honest disinclination to adopt meters, arising largely, it seems, from the fact that so little can be predicted of the effect of their general use upon revenue, and from the difficulty of devising rates that will be just and fair to all classes of consumers.

There is, of course, the ignorant opposition based upon the belief that meters will make water scarce and high, and the opposition that seeks political advantage by the false cry of a free and abundant supply of water, neglecting the fact that in few, if any, works is there any charge whatever for water itself, but only for bringing it to the consumer at less expenditure of time and money than he could bring it from a pump in his yard, if the well and pump were furnished to him without cost

There is still a strong disinclination to adopt a meter system rather than provide at much larger cost a new supply or additional piping or pumps when the available supply is getting short. This is largely due, however, to a natural preference for a " sure thing." As further experience shows that the use of meters is certain to reduce a large per capita consumption of water, and furnishes us with absolute data from which to estimate what it will do in this respect, this obstacle to their adoption will disappear.

If, then, methods of fixing meter rates were available by which the problems and difficulties now attending the change from fixture rates to meter rates could be eliminated or greatly lessened, the general use of meters would make rapid progress.

Your committee believes that its proper work lies in this direction: namely, of suggesting, if possible, some method or methods for fixing rates that will avoid some of the difficulties now apparently inherent in the change to meters, and which those works already having a partially metered system will find more satisfactory for an entirely metered system than the rates now in use.

The committee does not believe that it is desirable to attempt to fix a scale of prices. In its opinion this would be most impracticable, and no such scale could be devised that would meet with general adoption. It is desirable, however, to establish some basis upon which a scale of prices can be devised for any particular system, giving consideration to the conditions prevailing in such system.

Desiring to do its work with as full knowledge of present practice and its results as possible, the committee sent blanks asking for information and statistics relating to the meter system in the works under their charge to the members of the Association, and received seventy-two replies. This information has been tabulated as far as seemed desirable, and this tabulation and a general summary of some of the results are appended to this report.

The committee then took up the question and tried to ascertain just the problem that was before it, and gives the following as its conception of it.

THE PROBLEM.

The problem is to devise a method or methods by which meter rates can be arranged that will most nearly meet the following requirements, and do so with substantial justice to all classes of consumers and the greatest possible simplicity of operation.

REQUIREMENTS.

First, to insure a sufficient revenue to meet the demands of the system, whether it be a municipal system, operated practi-

cally at cost, or a system owned by a private company upon which a reasonable profit must be secured.

If a sum is raised by taxation for fire protection (as there always should be if justice is to be done between consumer and taxpayer), that sum must, of course, be deducted from the amount of the total maintenance to find the amount necessary to be raised by meter rates.

Second, the method should be sufficiently flexible so that the rates may be easily changed in case of a deficiency or surplus of income.

Third, the method should allow of the use of meters upon services with a single faucet without increase over the faucet rate, unless for actual use or waste of water. It should also secure from large, well-plumbed places a reasonable amount to meet fixed charges, even if little water is used.

Fourth, the method should meet the conditions of places with a fluctuating population and a large seasonal use of water, such as summer and winter resorts.

Fifth, the method should be such that it can be adapted to the different conditions of works in which the fixed charges are high and the operating expenses low, as in gravity systems, and where perhaps a large use of water at a low price is desirable; or where, on the other hand, the fixed charges are lower in comparison with the operating expenses, as in a pumping or filtering plant, and where it is desirable for any reason to be prudent in the use of water, and where large use at low rates cannot be encouraged. The method should be one that will meet the requirements of a "flat rate," with no discrimination between users of water, and still permit the supplying of large users such as factories at a cost that will not be prohibitive in cases where it is desirable to encourage such use.

SUGGESTIONS.

In view of the foregoing and as the result of its study of the subject, the committee suggests the two following methods of assessing rates for supplying water through meters:

First, the assessment method.

This is considered by the committee as the most scientific method, and one adapted for general and permanent use.

Second, the multiple minimum rate method.

This method, which is called the "multiple minimum rate" method to distinguish it from the single minimum method now largely in use, while not considered by the committee as so suitable for all conditions as the first, or "assessment method," is well adapted to securing a revenue similar to that obtained by fixture rates in works where the change is being made from fixture to meter rates, and where there are no data relating to the probable consumption with meters. In new works also it may be possible to estimate more closely the probable revenue to be received than with the first method. The following discussion will treat the two methods more in detail.

THE ASSESSMENT METHOD.

By this method the rates will be assessed as follows: A constant sum will be assessed each year upon each property based upon the frontage of the lot on one street, and without regard to the amount of water used. In addition to this assessment, a certain price per 100 cubic feet or 1 000 gallons will be charged for all water used through the meter.

FRONTAGE ASSESSMENT.

There are certain expenses of a water-works system which must be met as long as the works are operated, which are affected but little, if at all, by the amount of water used. These expenses should be met by a revenue which is also independent of the amount of water used. The total amount of such expense is dependent more upon the length of the piping system than upon any other element of the plant. The amount of water used affects the capacity of the pumping plant, but not in direct proportion, and in many works not at all. The requirement for fire protection fixes the pumping capacity. The amount used affects the capacity of the supply, but not necessarily its distance from the center of distribution.

The frontage of the lot affects materially the total length of the piping system. Therefore there seems no other element

which can serve so well and so justly as the measure of the constant yearly assessment as the length of frontage of the property. It is not material to the method how the frontage which shall be assessed is determined. It is probable that a municipality can assess all property, both that built upon, and vacant lots, while a company can only assess upon existing houses and their lots. It would seem to be fair that all buildings should be assessed, whether occupied or not. This, however, is not essential to the method. If vacant lots were not assessed, some limit to the amount of land to be assessed with each building would be necessary; for instance, each lot might be assessed upon a length not exceeding twice or three times the width facing the street, of the building upon it. A corner lot might be assessed upon one street only, or, as in the case of sewers, a certain frontage of the second street might be exempt. These details are not essential to the principle, and should be decided by the conditions of each case.

The exact proportion of the total annual expense of maintenance which should be assessed in this way is not essential. It seems to the committee, however, that it would be substantially just if, in ordinary cases, one half of the total amount to be raised were assessed upon frontage and the balance raised by meter rates based upon the total consumption. The price per 100 cubic feet, or 1 000 gallons, in any place would then depend upon the total consumption. Taking the average place, it might be about 7½ cents per 100 cubic feet, or 10 cents per 1 000 gallons, based upon the water that would be measured through the meters.

The above is a brief description of the method. It must be examined to see how it will meet the requirements.

First, to insure a sufficient revenue.

In new works, or in those which are changing from a basis of fixture rates to meter rates, there are very few data upon which to estimate the probable consumption of water after meters are installed, or rather the amount of water that will be measured through the meters. It cannot be estimated with precision how much the use of meters will curtail the total amount pumped or drawn from the source, and of the total amount the quantity measured depends upon the leakage in the piping system, the

slip of the pumps, etc. In many cases of gravity supplies, there is no knowledge of the quantity of water drawn.

This method of assessing one half or a fixed proportion of the total annual expense upon frontage assures that a certain sum will be secured, and thus reduces the percentage of error by making the sum that is based upon the probable consumption much smaller. After one or two years' experience with meters, the amount passing through them can be closely approximated and a rate established that will secure the amount required with as much accuracy as necessary. There is no system possible under which the exact revenue can be established, and this is not necessary.

Second, flexibility.

While it is not desirable to change water rates frequently, it sometimes happens that the conditions permit of their being reduced, and it is conceivable that under some circumstances they must be increased. As compared with fixture rates, or even with meter rates, based upon a minimum charge, this method offers a very simple way of changing the rates, and the approximate results of the changes can be closely estimated.

In case of a reduction. If it is considered desirable to have the price of water low, and encourage its use, the assessment can be maintained as it is and all of the change made in the rates, when the preceding year's record of consumption of water through meters will furnish a basis upon which to estimate the rate necessary to secure the desired reduced revenue.

On the other hand, if the supply is rather limited, or the cost of securing and delivering the water is considerable, and it is desirable to conserve the water, the assessment can be reduced and the rate maintained. It is probable that the law of demand and supply would be operative with water as with any other commodity, and a high price for water would tend toward a prudent use, and a low price toward a lavish use.

Third, satisfactory use of meters in all classes of services.

It is believed that this method will allow the use of meters on services with only a single faucet, and also in large houses in which little water is used, with substantial justice and with satisfactory results in revenue to the department. Aside from occa-

sional exceptions, houses with a single faucet are small and on narrow lots, while large, well-plumbed houses generally have greater frontage. These different classes of property would bear their proportion of fixed charge in a fairly equitable manner. As long as each pays its fair proportion of fixed charges, there is no reason why a single faucet using large quantities of water should not pay for it, and on the other hand, why a large, fully-plumbed house should pay for water which it does not use.

Fourth, for summer and winter resorts.

This method seems very well adapted to the conditions in places where there is a great fluctuation in the use of water. Those consumers who actually use water for only a few months in the year must pay the fixed charges for the entire year through the assessments, and if they use a very large quantity of water during their short stay, pay for that at meter rates.

While places of this sort need metering as a means of water-waste prevention more than many other places, it is very difficult to meter them under the methods of fixture rates now in use. The transient consumers, while using large quantities of water for a short time, do not use enough in the whole year to exceed the ordinary minimum rate, and thus, while making it exceedingly difficult and costly to supply them while in town, do not do their share (under ordinary meter rates) toward supporting the works, the fixed charges of which are tremendously increased by their requirements.

This class of consumers would be reached through the frontage assessment, and in such places the portion of the entire annual cost which was assessed upon frontage could be larger than in places with more normal conditions.

Fifth, adaptability to differing conditions.

It is evident that a gravity system with a large sum invested in the plant and very small operating expenses is furnishing water under entirely different conditions than obtain in a pumping system in which the plant is of much less first cost but with large expenses for pumping.

If the first system has an ample supply, it costs no more (within certain limits) to furnish a large amount of water than a small one. With regard to the furnishing of water, almost

all of the expenses are in the nature of fixed charges, and the net revenue of the works is directly increased by the sale of additional water at almost any price. In such a case it is, no doubt, good policy to encourage legitimate use of water in large quantities in a way that could not be done under a "flat rate" if the entire annual expenses were raised by meter rates of so much per one hundred cubic feet. With such rates, nothing but a sliding scale of prices would accomplish the result.

In such a case as stated above, the proposed method provides a way to adopt a "flat rate," and also to encourage the use of water in large quantities without discrimination. By assessing a very large proportion of the annual cost upon frontage, and raising a small proportion by meter rates, the price can be made very low and the same to all consumers. In such a system it is certainly just to assess a large proportion upon frontage, for as already shown, its expenses are largely composed of fixed charges, which, on account of their nature and origin, it is equitable to assess upon frontage.

On the other hand, this method can be as well adapted to a pumping system with a comparatively low first cost and high operating charges by assessing a small proportion of the annual cost upon frontage and raising a larger proportion by meter rates. This would also be equitable, as in such a system the operating expenses would be largely affected by the consumption.

Below are a few examples of how rates might be fixed under this method in places with differing conditions. In these places, the names of which are not given, actual figures from the reports of a certain year are used.

The first is a pumping system with about 29 000 population. The works cost practically $1 600 000, with 105 miles of pipe. Annual expense, including interest and sinking fund, $106 000. Consumption, 464 000 000 gallons.

Frontage. In determining the length of frontage to be assessed, it is a simple matter to measure the lots, much easier in fact than to go through the house for a list of fixtures, as must be done under fixture rates.

In this estimate it is assumed that on each side of the pipe line the length of assessable frontage will be one half of the total

length of pipe, after excluding pipe not in streets, the length of street crossings, that passing vacant and unassessable lots, etc. Then on both sides of the pipe line there will be the same length of frontage as there is length of pipe; in this case 105 miles, or 554 000 feet of frontage. There was an appropriation of $18 000 from the tax levy, leaving a net amount to be raised of $88 000. Assuming that one half, or $44 000, will be assessed on 554 000 feet of frontage, will make an assessment of practically 8 cents per front foot. The remainder of the expense, or $44 000, is to be raised by meter rates. The consumption was 464 000 000 gallons per year, of which it is probable that about 65 per cent. would go through the meters, or about 300 000 000 gallons, making about 14.6 cents per 1 000 gallons, or about 11 cents per 100 cubic feet. It should be noted that the consumption per capita in this place was low, about 50 gallons daily, and the cost of water based upon total pumpage and total expense high, or about 23 cents per 1 000 gallons; the meter rates were high, 35 cents per 1 000 gallons. The minimum rate for meter was $10, and the amount of water allowed under this minimum about 28 700 gallons per annum, or about 80 gallons per day.

Assuming a fully plumbed house on an 80-foot front lot, using the above amount of water, the charge would be as follows:

Assessment, 80 feet @ 8 cents	$6 40
28 700 gallons @ 14.6 cents	4 20
	$10 60

If double the amount of water, total $14.80.

Or, assume a small house with one faucet on a 40-foot lot:

Assessment, 40 feet @ 8 cents	$3 20
An amount of water equal at 35 cents per 1 000 gallons to $5, or single faucet rate; or 14 350 gallons per year @ 14.6 cents	2 10
	$5 30

Take a smaller pumping system in which the per capita consumption was about 60 gallons, and the cost of water based upon the total pumpage 8.5 cents per 1 000 gallons. Total cost of works, $80 000; 8 miles of pipe.

Total annual expenditure	$6 500 00
Appropriation	1 500 00

Total pumpage of water, 76 400 000 gallons yearly. Assume the same proportion of frontage as before, 8 miles, or 42 300 feet. Net amount to be raised, $6 500 — $1 500 = $5 000. One half on frontage, 2 500 ÷ 42 300 feet = about 6 cents per front foot. Assume that 65 per cent. of pumpage could be measured, or 76 400 000 × .65 = about 50 000 000 gallons. Dividing one half of the expense, or $2 500 by this, gives a meter rate of about 5 cents per 1 000 gallons.

Assume house as before with 80-foot lot:

Assessment, 80 feet @ 6 cents	$4 80
Assume that this is an average service in use of water. The average use per service was 50 000 000 gallons divided by the number of services, 343, making 145 000 per year at 5 cents	7 25
For house using average amount of water	$12 05

Small house using one faucet and 50 000 gallons:

Frontage, 40 feet @ 6 cents	$2 40
50 000 gallons @ 5 cents	2 50
	$4 90

If this house had 80 feet of assessable frontage, its bill would be $7.30. If it used only 30 000 gallons of water per year, its bill would be $3.90.

Take a gravity system in which the per capita consumption was about 80 gallons and the total consumption was 427 000 000 gallons, and the cost of water based on total consumption 8.8 cents per 1 000 gallons. Total cost of works, $555 000; 42 miles of pipe. Total annual expenditure, $37 500; appropriation, $8 700; amount to be raised from consumers, $28 800.

If one half of this sum is assessed on frontage, assuming amount of frontage as before, the assessment per foot will be 6.5 cents. Assuming 65 per cent. as the proportion of the total consumption which can be measured by meter the rate would be 5 cents per 1 000 gallons.

The frontage rate was low on the above division of expense, and if it was thought desirable to reduce the water rate, the assessment could be increased to 8 cents per foot, which would reduce the water rate to about 3.6 cents per 1 000 gallons.

It must, of course, be understood that there was one assumption in all of the above cases which may or may not be approximately correct; namely, the assumption that the assessable frontage on each side of the pipe lines was equal to one half the total length of the lines, or that the total assessable frontage was equal to the length of the lines. The facts in any particular case would undoubtedly be different. If the assessable frontage exceeded that of the assumption, the rate of assessment per foot would be less; and if the frontage was less, the rate would be greater. This does not affect the principle and would not change the rate per 1 000 gallons for water, which would remain the same in the examples given unless the annual expenses were divided differently between frontage and rates.

THE MULTIPLE MINIMUM RATE METHOD.

This method fixes minimum rates to be paid for different kinds of fixtures in use, and a price per 100 cubic feet, or 1 000 gallons, for all water used in excess of the amount paid for by the minimum rates at the schedule price. As many or as few fixtures may be used for the basis of the minimum as is considered desirable in each case.

For simplicity in accounts, it seems better to take only a few of the important fixtures as the basis. The method also fixes what may be called a total minimum, which allows the use of water for all purposes without consideration of the number or kinds of fixtures.

As an existing example of this method, the schedule of rates for the water works of the town of Merrimac, Mass., is given below. It is proper to state that these works are only recently in operation, and the method of water rates has not been tested. All services are metered in these works.

METER RATES FOR THE MERRIMAC WATER WORKS.

All water consumers will be furnished with water through meters, and the following rates will be charged:

For 10 000 cubic feet or less annually to one customer, per 100 cubic feet, 25 cents.

For more than 10 000 and less than 20 000 cubic feet, annually per 100 cubic feet, 20 cents.

For more than 20 000 and less than 50 000 cubic feet, per 100 cubic feet, 15 cents.

No water will be turned on to any premises except upon payment of a yearly minimum charge of $6.00.

This will entitle the consumer to use water at meter rates through faucets for all purposes, except as specified below.

For use in water closets there will be an additional yearly charge of $5.00. This will entitle the consumer to use water at metered water rates through water closets and urinals of all kinds.

For use in bath tubs, an additional yearly charge of $4.00. This will entitle the consumer to the use of water at metered rates in bath tubs.

For use of water through hose, an additional yearly charge of $5.00. This will entitle the consumer to the use of water at metered rates through hose for all purposes, including sprinklers, fountains, and troughs.

The above minimum charge covers the use of water by one family or consumer at metered rates for all of the purposes for which the water is supplied by the system. No further charges will be made until the amount of water used in any quarter exceeds at meter rates the amount of the minimum charges paid for that quarter.

Any consumer paying minimum charges amounting to $20.00 per annum will be entitled to the use of water at meter rates for all purposes without regard to the fixtures in use.

The minimum charges must be paid quarterly in advance within fifteen days of date of bill.

Bills for water in excess of minimum charges will be sent out at the beginning of each quarter for the preceding quarter and must be paid as above.

The department will provide, set, and keep in repair the meters, except where they are injured by freezing, or by the neglect or carelessness of the consumer, when it will repair or replace them at the expense of the consumer. They will remain the property of the department, and the consumer shall provide and maintain a suitable place for them of easy access for reading and inspection.

It can probably be said for this method that it will meet the first requirement, namely, that of raising a certain revenue, better than the assessment method and, in fact, better than any other method yet suggested.

It will not meet the second requirement, that of flexibility, as well as the assessment method, or as well as a straight meter payment without a minimum rate.

It is exactly adapted to meet the third requirement of providing for the use of single faucets, and at the same time securing a proper return from fully-plumbed houses, and we believe will do it better than any other method.

It will meet the fourth requirement, or that for the conditions in summer and winter resorts, very well, perhaps as well as the assessment method, and much better than a single minimum.

It does not meet the fifth requirement, or that of providing for a very low rate for use of large quantities of water at a "flat rate," and no method will which does not include a definite and separate provision for an item to meet the fixed charges of the system.

In making the foregoing suggestions, the committee does not wish to seem to condemn or even to criticise any existing method of meter rates. Some are, no doubt, working to the satisfaction of the works using them, and such works being adapted to those methods might find little advantage in changing.

For works that are not satisfied with their present system, for works that contemplate changing from fixture to meter rates, and for new works, the suggestions of the committee may have value.

The committee also wishes to express its opinion on the following:

That it is desirable for the water department to purchase, own and repair the meters.

That all public buildings, watering troughs, fountains, etc., should be metered, whether or not payment is received for the water so furnished.

That all gravity works should be provided with a meter for measuring the total draft.

TABLE ACCOMPANYING REPORT OF COMMITTEE ON METER RATES, SEPTEMBER, 1905.

Number	City or Town	How many services?	How many meters?	Percentage of metered services?	How many services have only a single faucet?	What was the total consumption last year?	What was the total quantity metered last year?	What were the total receipts for water last year?	What were the receipts for metered water?	Does the department own the meters?	Does it charge rent for the meters?	How much?	Does it require deposit?	How much?	Does it place meters on services with single faucet?	Does it have a minimum charge?	How much?	What amount of water is allowed for the minimum charge?	How many metered services use less than the allowance?
1	Atlantic City, N. J.	4 630	3 913	85		1 133 501 500		$115 778 08	$101 608 52	Yes	No		No		Gen'ly not	Yes			3 459
2	Attleboro, Mass.		1 567	100		170 215 000	88 051 500	29 876 22		Part of them	Yes	$2 per month			Yes		$6 00	2 600 cu ft	406
3	Bath, Me.	2 060	105	5	856	726 233 300				Not house meters	No				No		20 00	8 000	65
4	Beverly, Mass.	3 485	111	3		105 598 790	15 819 000	13 021 50	6 872 89	Yes									
5	Billerica, "	264	142	54	72	29 151 887		3 861 37	2 425 68	No						Yes	12 00	10 000 gals	71
6	Bridgeport, Conn.	9 500	400	4		6 570 mil. gal	1 000 mil. gal		Private Co.	Yes						No			
7	Bristol,	1 250	41	4	350		17 364 038		1 800 80						Yes	Yes	25 00	8 330 gals	7 or 8
8	Brockton, Mass.	5 849	5 299	91		539 199 311	299 205 468	80 693 35	80 577 70		Yes	$1 50 for ⅝			No		8 00	27 000	
9	Burlington, Vt.	3 524	2 680	76	Very few	319 163 200	101 251 000	39 659 68	6 487 59		No				Yes		6 00	1 000 cu ft	About 1100
10	Claremont, N. H.	822	152	19				13 817 91	1 232 01						No		12 00	60 000 gals	10
11	Cleveland, Ohio	60 627	30 226	49		22 545 380 000	8 859 116 000	776 157 62	507 525 36						Yes		2 50	17 000	11 000
12	Clinton, Mass.	1 743	1 117	82	283	211 136 055	93 321 112	29 731 73	22 262 99	Yes	Yes	$1 50	No		No	Yes	6 00	2 400 cu ft	About 225
13	Concord, N. H.	3 376	1 272	38				65 088 45	4 099 23		No						2 50	1 700 cu ft per quarter	797
14	Dartmouth, N. S.	670	4	1				8 075 00			Yes								
15	Des Moines, Ia.	9 509	6 500	68		1 010 154 220						$2 00	No		Sometimes	Yes	4 00	150 cu ft per month	775
16	Detroit, Mich.	61 165	5 847	10		18 757 682 350	1 974 518 372	398 290 00	1[illegible] 176 40		No				No		1 75 per quar	30 000 gals	
17	E. Providence, R. I.	993	686	69	350										Yes		10 00	33 333	100
18	Fairhaven, Mass.	600	200	33		120 000 000				No					If desired		10 00	33 000	
19	Fitchburg,	4 695	2 712	58	150	1 058 500 000		63 025 56	[illegible] 318 73	Owns 191					No	When city owns meters	10 00		1 000
20	Gloucester,	3 190	160	5	*one half	103 318 598	60 000 000	56 131 75	11 237 03	Yes						Yes	2 00	67 000 gals	
21	Gloversville, N. Y.	3 186	300	9				58 170 75	10 127 14								3 00		Very few
22	Greensburg, Pa.	2 421	2 656	100			313 227 282	90 678 00	67 831 75				Yes / No	$3 00	Yes		12 00	20 000 gals	
23	Hartford, Conn.	10 000	9 600	96				246 130 39									5 00		
24	Haverhill, Mass.	5 650	662	12				90 701 00	[illegible] 098 00		Yes	10% on cost			No		10 00	128 gals per day	Four fifths
25	Holyoke,	3 719	247	7			170 267 250	105 053 88	23 632 34			10 to 12% of cost			Mount'g elevator or mercantile bldg	No			
26	Indianapolis, Ind.	11 240	900	6		5 713 371		310 801 01			No		Sometimes			Yes	16 20	7 500 gals per mo	
27	Jacksonville, Fla.	3 270	1 706	52		861 301 712		65 057 27		All ??				$6, $8 & $12	Sometimes		8 and 12	300 gals per day	
28	Kewanee, Ill.	600	600	100	*10%	75 362 500	48 126 900	10 812 00	10 812 00	Yes	Yes		No		Yes		5 00	1 700 cu ft year	Close to 33%
29	Knoxville, Tenn.	5 600	1 677	30	2 173	1 010 300 000	151 610 000	106 653 00	59 712 00			From $2 to $6 yearly			No		10 00	13 000 to 30 000 gals per yr	
30	Leominster, Mass.	2 353	711	30	293			50 362 80	13 115 07		No						10 00	5 000 cu ft	
31	Manchester, N. H.	6 000	4 000	67	Very few	1 100 000 000	410 000 000	127 000 00	86 000 00						No		10 00	8 000	300
32	Marion, Ohio	890	653	73	*250	210 258 315	63 141 815			47%					Yes		2 50 quar	10 000 gals quarterly	About 60%
33	Marlboro, Mass.	2 258	1 266	56		207 874 800	880 778	12 725 80	21 166 02	No			Yes	$12 00			6 00	1 777 cu ft	
34	Milton,	1 173	1 173	100	131	8 865 960 cu ft	8 865 960 cu ft	29 475 59	All water metered	Yes			No				8 and 36	2 300 & 4 800 cu ft	
35	Montclair, N. J.	2 650	2 650	100	Very few	350 000 000							Yes	$5 00			10 00	1 145 cu ft	About ⅓
36	Montreal, Can.	61 395	1 108	2		8 970 392 601 imp gals	825 801 797 imp gals	808 479 33	139 806 16	[illegible]	Yes	[illegible]	Chinese laundries only	$15 00					
37	Muscatine, Ia.	1 240	100	8	None	199 279 355	37 065 850	20 091 12	5 707 25	Yes		10% on cost	No		No	Yes	10 00	25 000 gals	None
38	Nashua, N. H.	*4 000	657	16		1 118 613 850					No						16 00	80 000 "	
39	New Bedford, Mass.	9 927	1 954	19	*750	2 535 280 580	772 887 000	124 121 26	12 202 26	765							5 00	33 333	Quite a number
40	New London, Conn.	3 463	278	8	Very few	564 088 000	297 020 000	60 607 34	24 133 50	Yes	Yes	10% of cost			If desired		10 00	33 333	Few
41	Newton, Mass.	7 404	6 367	86	600	700 810 000	184 000 000	128 172 00	125 278 00	About 90%		$1 50 for ⅝ and up			No		30 00	28 573 gals and up	About 10%
42	New York City	120 844	6 273	5		38 232 818 100	6 533 459 300	2 420 082 33	871 181 21	No									
43	Oberlin, Ohio	700	512	73	*150	55 600 000	21 700 000	7 657 80	4 567 80	⅘ of them	Yes	$1 50 per year	No		If desired	Yes	5 00	2 240 cu ft	About 100
44	Paterson, N. J.	11 735	3 051	26			87 120 700 cu ft		97 368 08	Yes	No		From tenant only	Depends on amt used	[illegible]		12 00	1 300 cu ft per quarter	About 60%
45	Portland, Conn.	550	30	6	100								No		[illegible]		15 00 fixture rate	60 000 gals	None
46	Portland, Ore.	19 173	750	4				803 446 25							Yes if [illegible]			Quantity paid for by schedule rate	About [illegible]
47	Quincy, Mass.	5 327	165	3				86 045 20		No					If desired		18 per yr	60 000 gals	75%
48	Reading, "	1 162	1 035	89		53 202 932		10 155 12	10 155 12	Yes			No		Yes		6	16 000 "	600
49	Reading, Pa.	17 603	952	5		3 292 153 709	1 130 258 679	175 447 53	12 257 00	Yes with few exceptions					No				
50	Rockville, Conn.		239		51		12 000 000			Yes	Yes	$1 per yr for small, 10% per yr for large; ⅝" $1 50, ¾" $1 50, 1" $2, 1½" $[illegible], 2" $6			Yes	Yes	6 00	25 000 gals	
51	Rutland, Vt.	2 162	None	0	..	2 000 000 gals per day		29 190 16							Not [illegible]	Y	1 50 each [illegible]	1 250 cu ft	Few
52	Somerville, Mass.	11 059	1 537	14		2 279 637 000	116 097 066	216 027 31	6[illegible]		No								
53	Spencer, "	*800	759	95															
54	Springfield, "	10 171	3 708	36		1 270 500 000	519 780 743	238 673 13	86 [illegible]	No	No								
55	Stapleton, N. Y.	3 267	1 500	46	700	100 000 000				Yes			No			Y	2 50 per qr	7 00 cu ft per quar	About [illegible]
56	Syracuse, "	18 088	10 063	54		12 254 000 daily		268 088 56	18[illegible]	About 500							5 00	[illegible] cu ft per mo	5 000
57	Tarrytown, "	700	678	96	None	203 961 000	70 000 000	16 117 95	1[illegible]	No					[illegible]		1 per qr	[illegible]	97
58	Taunton, Mass.	4 753	2 134	45	750	551 061 530	262 095 115	61 215 76	42 107 06		No				[illegible]		33 00	10 000 gal	900
59	Waterbury, Conn.	5 388	518	10	187	308 137 500 cu ft	58 231 714 cu ft	138 121 09	57 [illegible] 50	Yes	When less than [illegible] and is not consumed	$2 to $8 per an	No				5 00	17 000	10
60	Waterford, N. Y.	723	406	56		143 047 500	40 316 000 gals	Private		Dept. & consumer	If consumer desires to rent	10% of first cost			[illegible]	No			
61	Watertown, Mass.	1 730	1 505	92	135	182 500 000	89 631 800	33 173 30	3[illegible]	Yes	Yes	$1 00	Yes	$10 00		Yes	10 00	1 000 cu ft	656
62	Wellesley, "	966	914	90	340	107 202 000	55 085 964	18 352 69	1[illegible]		No		No		Yes		6 00	16 000 gal	300
63	Westboro, "	648	630	97	150			10 054 07	[illegible] 07		Yes	[illegible] $1 50; larger 10% of cost	Yes	$5 00			[illegible] 00	16 725 gals per an	225
64	Westerly, R. I.	1 375	1 088	80	104	221 053 000		21 370 18	1[illegible] 07	Majority owned by consumers		$1 per annum					10 00	[illegible] gal per [illegible]	767
65	Whitman, Mass.	1 058	500	47		50 000 000		1 041 50	[illegible] 58	Yes		10% of cost	No		Sometimes		6 00	30c per 1 000 gal	[illegible] perhaps
66	Winooski, Vt.	282	254	90	200						N				If desired		2 per [illegible]	1 000 cu ft	[illegible]
67	Woburn, Mass.	2 6[illegible]	65	2		592 007 250	69 304 458	17 616 21	[illegible]										
68	Woonsocket, R. I.	2 557	2 251	88	192	365 667 963	286 190 728	81 433 94	57 [illegible]				Y	$10 [illegible]		Y	30 00	[illegible]	80%
69	Worcester, Mass.	14 129	13 380	95		4 565 818 440	1 620 727 680	270 651 66	268 [illegible] 66	No except 2" and up			No		[illegible]		4 00	16 000 gal per an	Quite a large number
70	Yarmouth, N. S.	1 180	0		175	240 219 826	6 547 475	22 507 88	[illegible]	Y									
71	Yonkers, N. Y.	5 675	5 804	100		1 713 770 000	971 884 000												
72	York, Pa.	10 060	263	3	6 030	929 361 868	371 758 000			Yes	N		No		[illegible]	Y	1 per [illegible]	[illegible] gal per [illegible]	66

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That a "flat rate" without discrimination between consumers of different amounts should be the rule, but that it should be accompanied by some method for securing a revenue to meet fixed charges independent of the amount of water used.

The committee also suggest the desirability of the general use of 100 cubic feet as a unit rather than 1 000 gallons.

It is very desirable that the gallon should be eliminated as a unit of water supply measurement and the cubic foot substituted. This change will undoubtedly come in time, but will perhaps be slow in coming, as the capacity of pumps, pipes, reservoirs, etc., are so universally given in gallons, and so many tables are based upon that unit. One million gallons also has a firm hold as a unit for large quantities. It is, however, a step in the right direction to use cubic feet in meter measurement, and the practice of doing so is already widespread.

Your committee wishes to say in conclusion that it submits this report with a profound sense of its inadequacy. It has not the confidence to speak of its propositions as "recommendations." It feels that its accumulation of data is so small, its knowledge of the subject so restricted, and its work so inadequate in comparison with that to be done, that it cannot speak with authority. It therefore makes suggestions which may be of some present value, but which can only be considered tentative and the work of a novice.

The committee believes that this work should be continued by the Association; that it should encourage its members to secure and make available all possible data bearing upon meter operation; that perhaps a committee on meter rates, or better, upon water meters, should be a permanent committee of the Association to accumulate information and bring the matter forward for discussion at convenient occasions.

It is the desire of the committee that its suggestions be thoroughly discussed and criticised, in the hope that more light may be shed upon this very important matter.

DISCUSSION.

MR. CLEMENS HERSCHEL.* As the Committee on Meter Rates has especially desired that its suggestions be discussed and criticised, the following is submitted. It has been written out, so as to give the careful attention to the subject which its importance deserves.

Very slowly a reform in water rates, made possible by the invention of house meters that can be manufactured at a moderate price, and by their improvement until they have become marvels of mechanical perfection, is taking place. But discussions such as this keep up the interest, and sometimes, and in most unexpected ways (as writer of this could testify), help on the good work.

Simplicity of operation, under the established water rates, appears to the writer to be of prime importance, and to attain this in the greatest degree seems to him to be reason enough for rejecting the plan of front foot assessment described in the report of the committee.

The substance and service furnished and to be paid for consists of water, under pressure, delivered into the consumer's premises. It is valuable not only as water, but also as an ever-ready safeguard against losses by fire — this last being of value, even though no water be actually drawn for a long term of years.

Water rates may, therefore, very properly consist of two parts: water supplied, and water held ready for extinguishing fires. Water actually used for extinguishing fires is so small in amount during the year that it does not disarrange the accounting to omit it from charges to be made.

We have then the insurance saving to the community by the presence of water under pressure, by hydrants, etc., which may well be a common charge to the whole community, to be paid for out of the tax levy; in a lump sum; or as hydrant rentals; and, secondly, water delivered in varying quantities to consumers.

Now, why it should make any difference to the water department what use the consumer makes of the water received, or where he uses it, the writer does not see, except in cases of a

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scarcity of supply, when luxurious uses — lawn-sprinkling, for example — may, by exercise of police-power, be prohibited altogether, for the purpose of preventing the failure of any citizen to receive a necessity of life.

The foregoing being accepted, we next arrive, naturally, at the selling of water by measure, or by meter. The writer's conception of a water meter is an instrument that will enable the total annual cost of a water supply (less hydrant rentals received) to be equitably distributed among its beneficiaries. Everything hinges thence on upon people's ideas of what constitutes an "equitable" distribution of this annual cost among the water consumers. And this, being an off-shoot of the great subject of taxation, gives room for opinion and for argument.

To the writer there is but one simple way, — to charge by quantity used and wasted; that is, "consumed" on the premises. If manufacturers, especially such as use large quantities of wash-water, are to be favored, as an inducement to settle in the community, or not to leave it, two ways present themselves for exercising such favoritism — their taxes may be remitted in whole or in part; or the principle of a sliding scale for water rates, based on quantity consumed, can be introduced.

The business of booming a town by means of charitable bequests in aid of coming or existing manufacturers, should not, however, be confounded or mixed up with the distribution of the annual cost of the water supply among those who receive water.

If it costs $50 000 annually to supply 1 000 000 000 gallons of water, this makes the cost per million gallons to that town $50. And if anybody pays only $30 for his million gallons of water consumed, then somebody else must pay the other $20. Shall it be the other water consumers, or the tax levy of that town? As a public or communistic enterprise, thus to relieve present, or to tempt intending resident manufacturers, there would seem to be more reason for meeting such charitable expenses from the common tax levy, than for saddling them upon the water takers alone.

For municipal water departments, this is not a parallel case to making a difference between wholesale and retail rates for an article offered for sale, for the reason that in the case of such articles, a profit is to be arrived at; and wholesale rates, though they

include a smaller profit per unit of measure than do retail rates, yet produce more of a profit in the aggregate.

But municipal water rates are not based on, or intended for the making of a profit. Their aim is merely to distribute in an equitable way, after the manner of mutual companies properly managed, such as savings banks, etc., the annual cost of carrying on the business, among its beneficiaries.

Should, however, the sliding scale of water-rates, from retail to wholesale quantities, be adhered to in the case of private water companies, or in the case of municipal water works who wish to range themselves in the company of sellers at wholesale and retail rates, such a sliding scale, diminishing with an increase of consumption, can readily be made to favor the large consumer. In such cases, the sliding scale should not include a temptation to consume more water for the purpose of attaining a lower rate and a lower aggregate charge.

An objection to meter rates, often heard from, relates to low-priced tenement houses, where waste is liable to go on in excessive amounts, and is not brought home to the wasters by the one meter in use as it is where only one family occupies the house: hence great outcry and objection from the owners of such tenements. But the remedy is clearly the use of more meters; one on each floor, or if need be, one to each family; precisely as the gas company manages such cases. There is no way to gain the active and continuous coöperation of the public in keeping their plumbing in order, and in shutting off the water when it is not being drawn for use, except by causing the result of any neglect on these lines promptly to appear in the next quarterly or monthly bill for water used and wasted.

It is to be regretted that the report of the committee gives renewed currency to the exploded fallacy that, with a gravity supply, "it costs no more (within certain limits) to furnish a large amount of water than a small one." This is equivalent to saying that wastefulness costs no more than thrift, and the day when this shall be true is surely as far distant as the suspension of the action of the force of gravity, or of that of any other law of the universe. The statement made by the committee is apparently — but only apparently — true for one year of operation, but is evidently not

true for ten or twenty-five years, or longer. Working on the basis first named has called for tens of millions of dollars of expenditure for "extending the water works" in the United States, when for ten and twenty-five years, even for fifty years, such expenditures should have been uncalled for and unnecessary. It also breeds a spirit of wastefulness in any community, with an article costing money to procure, which later it is exceedingly difficult again to remove. It has been largely responsible for that very disinclination to use reason in the management of water works, which the report of the committee aims to annul. No city receiving and paying for water by meter would ever think of putting forth such doctrine.

It is well to remember that cases are on record in which by nurture of the spirit of wastefulness, cities have attained a consumption on certain days of fully ten, and even twelve times the quantity which was ample for all their needs, and it requires no argument to prove that such cities have paid, and are paying, much more for water than they should, be it furnished by gravity, or by pumps, or both.

House meters are necessary for the prevention of waste on the consumer's premises. Equally necessary for the prevention of wholesale waste out of street mains and conduits, and, generally, to enable a proper accounting to be made of the whole operation of the works, are Venturi meters on these mains. The experience of the Metropolitan Water and Sewerage Board of Massachusetts should be conclusive on this point; not to mention that of the East Jersey Water Company, the details of which (this being a private water company) are, however, not so easily procured.

Nor can a counting of pump strokes take the place of a meter record, whether this be an occasional one, or a graphically continuous one. In fact, it has repeatedly been shown that the only way to keep a pump constantly in order is to have its pulse felt from time to time, or daily, by a meter; and to make repairs on valves or do other overhauling as the meter shows the need of them Without such watch upon the pump, counting the strokes may result in a variance from the truth of anywhere from 20 to 40 per cent.

As a final consideration, and with reference to flexibility of rates from one year to another, the writer suggests discounts on bills paid, or to be paid, precisely as this end is attained by the

general tax levy, or in the management of mutual savings banks, or mutual life insurance companies. It is very true that it is difficult to foretell the income and expenditures of a water department, and, generally, that the historian has a clearer field than the prophet. But such estimates need be no more embarrassing to the water department than they are to the other communistic enterprises above named.

All perfection in this world, or approach to it, is generally reached by successive steps of improvement and of approximation. Let any fair and competent estimate be made, therefore, of annual income and expenditures for the ensuing year; make an "overlay," precisely as the tax levy does, to prevent shortage, and then let the water takers have the benefit of the surplus, either at the office in cash, or as a discount on the next quarterly bill, or annually. Such annual rebate might even be made a popular feature of the conduct of the water department, awaited with interest, and no doubt meeting praise and blame, according to amount of cash thus put into the pockets of the water takers—where now there is blame only.

We have thus arrived at the conclusion that waste should be prevented and water paid for as gas or the electric fluid is managed and paid for: namely, strictly by measure of substance consumed on the premises through the meter of the party furnishing it, at uniform rates to all consumers, with the additional and superlative attraction that all profit (or in case of private water companies, all excessive profit, if any), made during any one year, is returned to the customer, pro rata, at stated intervals.

MR. ALLEN HAZEN.* The report of this committee marks an important forward step in the question of fixing meter rates. It recognizes a fundamental principle which, if carried to its logical conclusion, would go a long way towards doing away with the objection to meters.

It is altogether reasonable that the income to be derived from the sale of water should be made up of two parts, one of which is dependent upon the amount of water used, and the other of which is not. The latter class of expenses is represented by long lines of pipe, and by other parts of the system provided and not directly

* Consulting Engineer, New York City.

affected by fluctuations in the amount of water used, by the expenses of meters, services and book-keeping, and administration expenses generally.

Recognition of the fact that a certain proportion of the income is to be obtained for these matters, that is to say, as payments for the sake of having water available when it is wanted, will allow a lower price per thousand gallons to be put on water sold by meter. This will tend to prevent much of the dissatisfaction with meters, which comes, I think, from the feeling that the amount paid under existing schedules is often in excess of the fair value of the service, and I am afraid that there are cases where this feeling is fully justified.

The report of the committee will also tend to the simplification of schedules of meter rates, and to the adoption of more uniform methods. The variations of the schedules in use in different cities are surprising. A few years ago I prepared a diagram showing the amount of water which could be bought at meter rates in a year for given sums of money in a number of cities. This diagram is reproduced herewith (Plate I), and also a tabulated statement of some of the quantities.

TABLE SHOWING THE COST OF THE QUANTITIES OF WATER STATED AT METER RATES IN VARIOUS CITIES, IF DRAWN DURING A PERIOD OF ONE YEAR. COMPILED IN 1899.

Quantity of Water per Annum	Water Quantities in Thousands of Gallons.									
	10	20	50	100	200	500	1 000	2 000	5 000	10 000
Grand Rapids	$5 00	$5 00	$6 33	$13 33	$26 66	$66 66	$93 33	$186 66	$366 66	$600 00
Lancaster,	10 00	10 00	10 00	10 00	10 00	25 00	50 00	100 00	250 00	500 00
Milwaukee,	1 60	2 20	4 00	7 00	13 00	31 00	61 00	121 00	301 00	601 00
Albany,	6 00	6 00	6 00	8 00	16 00	40 00	80 00	160 00	400 00	800 00
Reading,	5 00	7 70	13 80	21 20	30 40	48 10	70 00	110 00	220 00	385 00
Madison,	4 50	5 20	16 00	23 20	36.60	62 00	85 00	130 00	330 00	660 00
Syracuse,	5 00	5 00	9 20	18 50	30 70	73 10	105 00	165 00	240 00	465 00
Berlin,	5 40	6 60	10 70	17 60	31 20	72 00	140 00	280 00	680 00	1 370 00
Lawrence,	5 00	5 00	10 00	20 00	39 00	93 00	170 00	320 00	720 00	1 300 00
Pittsburg,	5 00	5 00	10 00	20 00	40 00	100 00	195 00	345 00	600 00	1 000 00
Providence,	5 00	5 00	10 00	20 00	40 00	100 00	205 00	400 00	900 00	
Paterson,	5 00	7 10	14 20	28 40	54 00	89 00				
Paris,	4 00	6 40	12 00	24 00	48 00	115 00	220 00	380 00	760 00	1 300 00
Fall River,	2 80	5 60	14 00	27 40	53 20	110 00	200 00	350 00	730 00	1 200 00
Newton,	10 00	10 00	17 50	35 00	70 00	175 00	350 00	600 00	1 000 00	1 500 00
Gloucester,	5 00	10 00	25 00	50 00	100 00	250 00	470 00	850 00		
Average,	$5 25	$6 36	11 80	$21 50	$39 90	$90 50	166 00	$300 00	$535 00	$899 00

The difference in local conditions, in the cost of water, etc., may justify many of the variations in these meter schedules; but certainly such conditions cannot account for the wide differences shown, and particularly for the way in which the charges sometimes increase with progressive amounts of water used.

Some of the cities represented were clearly selling water to their largest consumers for less than the cost of producing and delivering it, at the same time charging small consumers rates proportionally above those necessary on an equitable basis for meeting the requirements of the works.

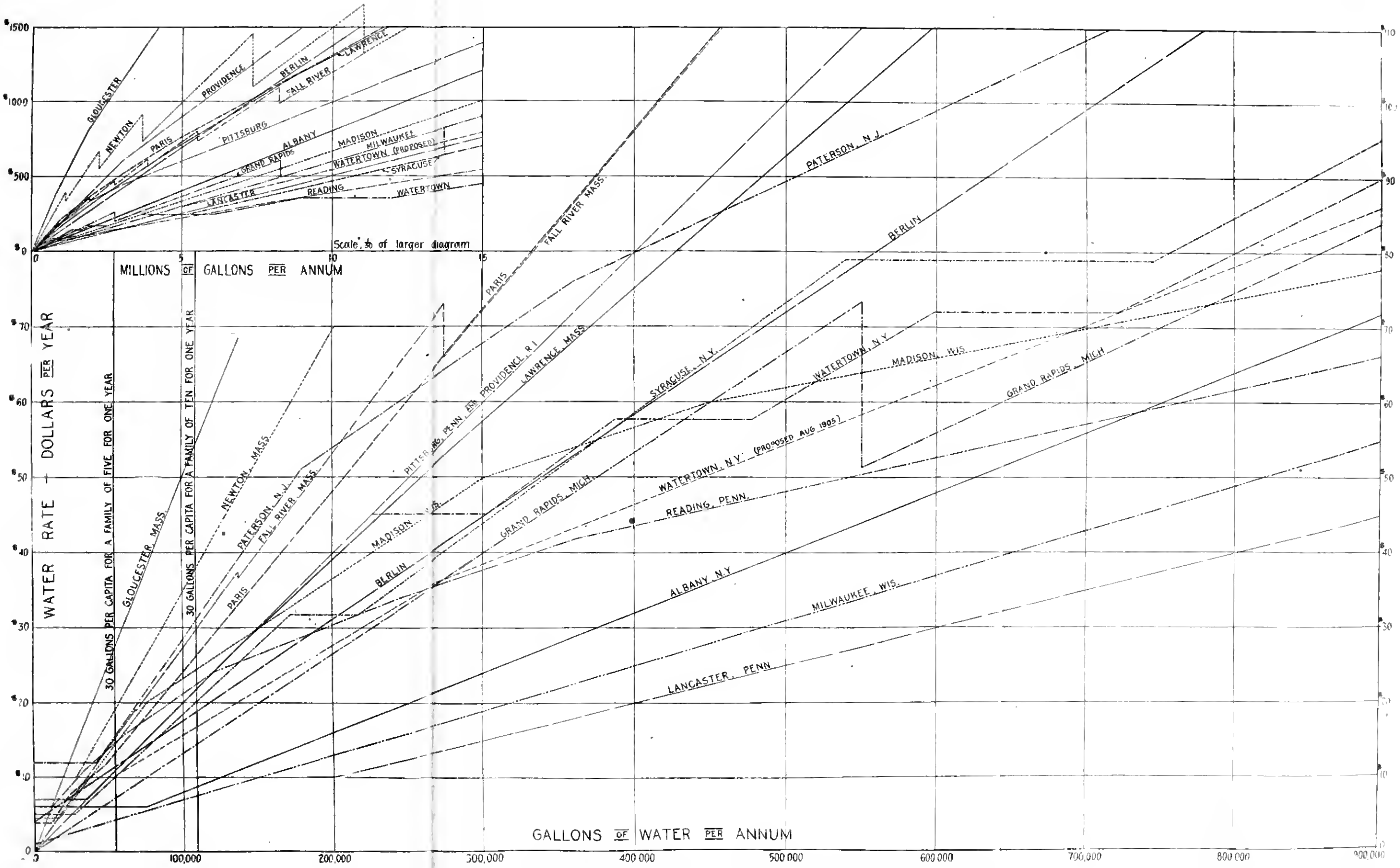
It is only fair to say that this information was collected some years ago, and that many of the cities represented have since corrected their schedule of rates. I present it without revision to illustrate the wide and unreasonable fluctuations in different cities, and not as a basis for criticism of any individual case.

It will be noted in the diagram that two of the schedules shown namely, the new schedule of Berlin, Germany, and the schedule of Milwaukee, have anticipated to some extent the report of our committee. That is to say, a charge of $3 per year for the service is made at Berlin, and of $1 per year at Milwaukee, and all water used is charged for at meter rates in addition to this, the idea being that the first item is an approximation to the expense of maintaining the service and meter, although the Milwaukee rate is undoubtedly too low to do this.

In large cities this scheme has something to recommend it. The proportion of the total expense, which varies with the quantity of water, would generally be larger in a considerable city, where the water works are used to a large per cent. of their ultimate capacity, than it would be in smaller towns, and particularly in places where works have been recently installed and the consumption is only a fraction of that which might be supported from existing works.

The method used at Milwaukee and Berlin is in line with the recommendations of the committee, but it is even simpler and it seems to be particularly adapted to the larger cities.

I indorse the report of the committee most cordially, at the same time recognizing, as does the committee, that the exact method of distribution and computation employed cannot be a



METER RATES IN VARIOUS CITIES. — ALLEN HAZEN, 1899.

universal one, but must be subject to study and adaptation to local conditions.

MR. EDWARD W. BEMIS.* It has been necessary in my conduct of the water department in Cleveland to study this question very carefully. To-day Cleveland has one fourth as many meters, and meters one fourth as much water as the entire total shown in the table presented by the committee. We have in use now 40 000 meters; four years ago we had only 3 000. We set 2 600 last month and will set as many more this month. We will set 15 000 this year. We have now everything metered except about 25 000 house services. We have metered about 40 000 services, large and small, and we are metering the others as fast as we can. Every service requiring a meter larger than a ⅝-inch is metered — every city building, every schoolhouse, every drinking fountain.

Having studied the question in this way, I should like to speak of one or two matters which are suggested by this report.

First, it seems to me that the discussion by Mr. Herschel has merit in calling attention to the fact that even in a gravity supply the waste of water is important, and for the reason which he has mentioned but which the committee did not seem to take into account, viz., that every ten or twenty years you have to extend your plant to reach new sources of supply, if there is a large waste.

The feature of the report of the committee which struck me as being very valuable was the idea of making the abutting land pay for the fixed charges, a matter which I notice Mr. Hazen has approved. That is certainly admirable. I have often desired information as to the extent to which abutting land pays for laying the water-pipe in the first place. I understand that in Milwaukee that is done in the case of all 6-inch mains outside of street intersections — that the entire cost of laying 6-inch mains is paid by a special assessment on abutting property. A recent law in Ohio allows that to be done, and it is being done. For instance, Lakewood, a suburb of Cleveland, is laying its water mains in that way.

And it seems to me that this is a very correct method, and one not at all out of harmony with the report of this committee, because the laying of a water main increases the value of the land

* Superintendent of Water Works, Cleveland, Ohio.

on the street more than the cost of the pipe. I hope some of the gentlemen here who know something about this matter will give us some information as to what other places, outside of Milwaukee and one or two cities I know of in Ohio, are doing in the way of making special assessment for laying water mains. That is certainly a matter which ought to be inquired into.

The difficulty, however, in applying the principle of the committee to the assessing of water rates, is, I think, especially to be considered in the case of large cities that already have their water supply. It looks to me like an admirable system in theory, and one which I think would work well in the introduction of a plant in a community, but there would be certain difficulties in applying it to a large city like New York or Boston or Philadelphia. There would be the conservatism to be overcome in the community, the application of a new principle of taxation for water works, something different from what the people are accustomed to, and something with which they are unfamiliar; and while that is not a fatal objection, it will, I fear, make the introduction of such a reform very slow; and it may, therefore, interest members of the Association to know how we attempted to tackle the problem in Cleveland.

We had to face the same difficulty which the committee had to face in introducing meters. We wished to make them popular, and we wished at the same time to foretell to some extent what the effect on our revenue would be. Of course we could not do that fully at the start. We have learned since much more than we knew at the time as to how little water is used by the average house consumer. We have had an analysis made of our 30 000 meter bills which were presented for payment in April; and I find that, excluding about 4 000 large meters, one half of all the rest average only 2 000 feet of water in six months, and one half of that number, or one fourth of all the residences, average only 1 500 feet, the other quarter of the residences averaging 2 500, making one half, or over 11 000 — about 12 000 of our residences out of those that we have metered — averaging only 2 000 feet of water.

In order to prevent too great a fall in revenue, and yet not interfere too much with the accustomed mode of getting revenue,

we adopted a series of minimums based on the assessment rate. Our rates were low anyway to start with, and yet we wanted a minimum so low that everybody would gain something by having a meter. It would not do, therefore, to have one minimum for $\frac{5}{8}$-inch meters, but the great problem was how to fix a minimum for $\frac{5}{8}$-inch meters, and yet make it an object for everybody to have a meter if he were prudent in the use of water. We adopted four minimums to start with. Those whose annual rates were \$4 or less could have a minimum of \$2.50, unless they used more water. Of course if they used more than \$2.50 worth of water they had to pay for it, but they had to pay \$2.50 anyway. That was paid in semi-annual installments, \$1.25 each six months. For those whose annual assessments were \$7 or less, there was a \$4 minimum, payable semi-annually. For those whose assessment rates were \$10 or less, the minimum was \$6, and for all others having a $\frac{5}{8}$-inch meter the minimum was \$8. Of course these particular figures would vary in other cities, but the idea of having four minimums struck us in Cleveland at the time as perhaps the only practical solution of the problem. We have since reduced those four classes to two, and we now have a \$2.50 rate for those whose assessment rate is \$7 or less, and a \$5 rate for all others using a $\frac{5}{8}$-inch meter.

The other plan that we considered was the Milwaukee plan. Milwaukee, as you know, has between 30 000 and 40 000 meters, — nearly 40 000, — which have been put in at the expense of the consumers of late years. There they do not have any minimum, but they charge a dollar a year for reading the meter. That system has its advantages, but the trouble with that, as we thought, was that if the city is advertising that it is putting in meters for nothing, as we did, we didn't think people would quite understand our turning around and charging them for reading the meter, and we really accomplished the same thing by our minimums. Our minimums do actually average two dollars a year for all the house meters in the different classes. So we have accomplished what they have attempted to do in Milwaukee, and we have at the same time met the great objection that has been raised by physicians against meters, that people wouldn't use enough water for their health, particularly in the poorer sections of the city and

where there are very hard landlords; for with our very low rate for water, of 40 cents per 1 000 feet, the minimum of $6 would allow the use of 129 gallons with a meter every day. So we entirely spiked the guns of those who were objecting to meters on the ground that they would restrict the consumption unduly.

Now we do not consider that scheme as scientific as that suggested by the committee of having fixed charges apportioned by special assessment, either on the entire land, which they intimate might be the better way, or on the improved property, which they think perhaps would have to be done as a matter of practical expediency. But I think, perhaps, it is easier of adoption and would accomplish a great deal in the way of getting at what we are after in cities that already have adopted the assessment rates, and where it is desirable to introduce meters without waiting for too great a reform in the method of obtaining revenue.

(*By letter, September 26.*) On further consideration of the report of the committee I conclude that this suggestion — to have the fixed charges paid by a special assessment on improved property — is not very different from the proposition that the city should pay the water department a liberal amount for fire protection and water for other public purposes, and should raise this amount out of the general tax levy. This would secure money not only from improved property, but from the unimproved, which the committee admits ought to pay something. This would not interfere with the suggestion I made in my discussion in New York that 6-inch mains should be laid by special assessment on all the abutting land.

MR. CHARLES W. SHERMAN.* The committee, although they do not say so in so many words, practically recommend a flat or uniform price for metered water after the minimum assessment has been paid. That is undoubtedly desirable in theory, and in many cities, perhaps, can be practically applied with satisfaction to all parties. It is not, however, always possible to do that, especially in the case of private water companies. A number of rates per 100 cubic feet or per 1 000 gallons is sometimes practically necessary. And in that connection I want to state as an example of "how not to do it" the rates of a private water com-

* Civil Engineer, Boston, Mass.

pany in Indiana which recently came to my attention, those rates having been fixed by the franchise of the company.

For a consumption not exceeding 100 gallons per day the rate was to be 40 cents per 1 000 gallons. For a consumption between 100 and 200 gallons per day the rate was to be 30 cents; between 200 and 300 gallons it was to be 25 cents; and between 300 and 1 000 gallons per day the rate was to be 20 cents per 1 000 gallons. No rate was fixed above 1 000 gallons per day. As you will readily see, a customer using between 200 and 300 gallons will pay the 25-cent rate for all his water; consequently there will be a point under that rate at which a man using say 201 or 202 gallons per day would pay a less total sum than a man using 190 or 195 gallons per day, if the rates were strictly adhered to. As matter of fact, I believe this particular company has made it an office rule that they would charge no party more for a smaller quantity of water than he would have to pay if he had used a larger quantity, although I do not know that that is specifically advertised. Under the company's rule there would be a certain range of consumption within which, therefore, the bill would remain the same whether the party used more or less.

What I wish to emphasize is the desirability, in case a variable meter rate seems necessary in a water system, of following a method by which the first 10 000 gallons per quarter, or whatever is a convenient unit, be charged for at one rate, and the next 10 000 gallons or some other fixed quantity of water, be charged for at the next (reduced) rate, the higher rate, however, applying, even in the case of a large consumer, to the first fixed quantity of water.

Mr. Walter H. Richards.* Mr. President, this subject is of interest to every water-works superintendent, if not at the present time, it is likely to become so very soon, because it is evident that we all will have to use meters in order to have water enough to go around. As to the rate, it seems to me that it is simply a business proposition. You have got so much water to sell. It has cost you so much to get it to the point where you wish to deliver it. Now, if you divide what it has cost you, that is, interest on your outlay and the cost of maintenance, by the

* Superintendent of Water Works, New London, Conn.

number of gallons you can furnish, you get approximately the lowest rate per 1 000 gallons. After you have got the water into the city, then it costs you something to get it into a house, and for a large quantity it costs you more than for a small quantity; hence you should have a minimum rate which varies. That is, a minimum rate for a small service pipe would be less than a minimum rate for a large service pipe. And I think we should have different rates, — that is, the rate should be less for a large quantity than for a small quantity. For I think we should consider somewhat what water is worth to the man who uses it. Of course it is worth more to the man who drinks it than it is to the man who uses it for manufacturing purposes — to make steam — and that should be considered in making up the rates. There is a large expense to keep the water pure; sometimes it has to be filtered, and all that is for the benefit of the householder — the man who drinks it — and hence he should pay a larger rate than the man who wants the water only for the purpose of making steam. It seems to me that each city should have a rate based upon its own peculiar circumstances, depending largely on what the water costs, but also upon other considerations.

MR. T. H. MCKENZIE.* There is one point which I think the committee have not covered in their report; that is, the matter of the life or term of usefulness of meters, or the length of time they can be used before they have to be removed and new ones substituted. I haven't very much experience with meters, but I will mention one instance where we put a 4-inch meter into a mill. At the time we put it in the mill was running only nine hours a day, but afterwards they commenced to run twenty-four hours, and in three years and a half the meter was practically worn out. We found out the condition of the meter in this way: the mill was using some 350 000 gallons of water per day; they substituted pumping for some uses — for cooling the furnaces and that sort of thing — and used our water only for boiler purposes; we found that certain days, when they were running perhaps six or seven hundred horse-power, the meter scarcely moved. Of course most of the small water works do not have facilities for testing meters and determining when they are worn out and when they

* Treasurer Water Company, Southington, Conn.

should be removed. I think that people who have had a large experience with meters can tell us something as to the ordinary life of a meter, either in terms of years or in quantities of water passed by the meter.

Mr. Hugh McLean.* I suppose this committee's object was to report on a uniform rate for selling water. Now, as I understand it, what we want to get over are the objections to putting in meters by devising some rate which will be as equal and equitable as possible; for instance, we put a meter in for a consumer, and the rate, we will say, is a sliding rate of 15 cents a thousand for the first 100 000 gallons, 10 cents for the next 200 000 gallons, and for all over that it is 5 cents per 1 000 gallons. We want to make it as easy as possible to get the meters in. Some user would say, "Why must I pay 15 cents for all my water?" And another would say, "Why should I pay 10 cents for mine?"

The idea I advanced at our meeting in Boston was to abolish these different rates, and to have one flat rate for all consumers, and in that way get rid of the objection to putting meters in, and make the matter very simple. The small consumers say, "We are citizens, we are equal shareholders in the water department with the large consumers of water, and we are entitled to have the water at as low a rate as the largest consumers; in fact, we ought to have the preference because we use it to drink, and to keep clean, and they use it for power and manufacturing purposes." When you start to put meters in, that objection faces you right away. So I argued in favor of abolishing the different rates and making one flat rate, which shall be as low as possible and keep the revenue up to what it was before.

Carrying out that idea, our water department has abolished the 15-cent rate, and we have now only two rates,— the 10-cent and 5-cent. By abolishing the 15-cent rate we lessened our revenue about two thousand dollars, but we added meters so that we increased our revenue about two thousand five hundred dollars and decreased our consumption from 159 to 105 gallons per capita — a saving of two million gallons a day. Now we propose to continue, and on the first of January we may abolish the 10-cent rate and have only one flat rate, and we expect the peo-

* Member Water Board, Holyoke, Mass.

ple will then allow us to put meters in, because we can say in all justice, "This water belongs to the community, to all the citizens equally, and we propose to see that it is sold at the same price to all." As it is now, the man who is using a small quantity pays twice as much for it as the man who is using a large quantity; and how can you stop that injustice, the giving of that benefit to the large consumer over the small consumer, unless you have one flat low rate?

Many business interests to-day are consolidating, and as a result they are getting water at the cheap rate. For instance, a mill which used 200 000 gallons of water every month paid 10 cents per 1 000 gallons for it. But 20 mills combine under one name and call themselves the American Paper Company, or whatever name they choose, and the 20 mills have their water bills lumped together, and they get all their water above the first 200 000 gallons at the 5-cent rate. Now how are you going to stop a consolidation like that from robbing your department, because the various concerns become one individual after they have consolidated, and they will buy the water as one and not as many?

The only fair, equitable way for a municipal department is to sell water to all the citizens at the one flat rate, which shall be as low as possible and yet furnish the revenue necessary to operate the department.

Now so far as the recommendation to assess property is concerned, I think that would be a step in the wrong direction. It would be in the line of double taxation. You might just as well argue that you should tax property for putting in gas pipes or electric-light wires or street railways. All those things increase the value of the adjoining property, and the owner of the property really has to pay for the improvement in value by increased taxes.

I think the simplest way is to charge so much annually for every hydrant for fire protection. That guarantees you a stated amount for each hydrant set by the department. As far as meters are concerned, the preferable way in my opinion is to set up the meter for the consumer and charge him a certain per cent. on the cost of the meter and for the labor in maintaining it, keeping it in good condition and reading it. If a meter costs $12, charge him say 10 per cent. on the investment, and that will be coming

back annually in the form of interest on the money you spend for meters. There should be only one price charged for water, just the same as there is only one price for any commodity that the government sells. Gas is sold at so much a thousand feet, the same to everybody; electricity so much a kilowatt; and water should be sold in the same way. That is justice, and all citizens are entitled to it.

MR. FRANK L. FULLER.* It has always seemed to me that the first use of water was for the householder, for the man who has to use it to supply his family. This is what the system is primarily introduced for. Now, why should a man who uses water for profit get it for a less price than a man who uses it from necessity, who must have it for the use of his children and for the ordinary domestic purposes? I think probably the large percentage of domestic consumption is by families in moderate circumstances, — a good many of them poor families, — who cannot afford to pay too much for their necessities. Why should a man who makes money out of the water, who uses it for manufacturing purposes, for making steam, etc., get it at a less price than the man who makes nothing out of it, but who uses it from necessity? In Wellesley we have one rate, and I thoroughly believe that, for the ordinary country town, that is the proper method. The greenhouse people there say, "We are using this water in our business, we get our living from our greenhouses, and we think we ought to have it at a cheaper rate." But our reply has generally been, "You use the town water because it is the cheapest water you can get; it is cheaper for you to use this than it would be to pump it yourselves; you make money out of your flowers, and why shouldn't you pay just as much for the water as the ordinary man who has a family, who makes nothing out of the water?" It seems to me that there is a good deal of force in that argument, and, so far as my observations have gone, that a reasonable flat rate is the better principle to go on.

MR. F. A. W. DAVIS.† This discussion may be getting tiresome to some of you, but the questions present so many different features and affect such different interests that it takes some time

* Civil Engineer, Boston, and member water board, Wellesley, Mass.
† President, Indianapolis Water Company, Indianapolis, Ind.

to go over the entire ground. Some suggestions have been made which I should like to answer. I am not going to criticise the report of the committee, for I think that it is an able report, and it certainly shows that the committee has spent a good deal of time upon it and given the questions considerable thought.

The reasons for setting meters are different. Some of them are as follows:

1. To stop waste.
2. To increase the revenue.
3. To avoid increasing the size of the mains.
4. To prevent surreptitious use of water.
5. To prevent one neighbor from supplying another.
6. To ascertain if consumers are paying as much as they should.

There may be other reasons, but these are sufficient.

It is somewhat experimental to set meters to increase the revenue, for it has often proven the means of reducing the revenue.

As to the use of meters making it unnecessary to increase the size of mains, it is questionable. Mains should be adequate and of sufficient size, for we are not at all times able to determine if it is legitimate or illegitimate use that incapacitates certain mains from delivering a reasonable supply to the citizens on the lines.

To prevent surreptitious use and neighborly accommodation is commendable.

So it is, in setting a meter, to ascertain if the quantity of water taken and paid for under the flat rate is greater than it should be. It has been found in the experience of nearly every water works that there are cases where the quantity of water used does not yield a revenue of one cent a thousand gallons.

The waste problem is comparable to that of taking coal without pay. A man without money, and with a family to warm, gets a wheelbarrow and helps himself to the coal pile of the water works. His visits become frequent and by and by he is detected, arrested, and sent to the workhouse. The man who wilfully throws down the hose on the lawn, turns it into the sewer or street, or allows his fixtures to run continuously, does for the water works the same thing as the man who takes the coal away in the wheelbarrow, the only difference being that in the first case the family get some benefit from the coal, while the man who wastes

the water gets no benefit for himself or others, and yet he gets away with the coal of the company. It may cost the company only hundreds of pounds of coal to furnish that man water, but if he makes it cost thousands of pounds of coal, he does the same thing as the man who takes it away in the wheelbarrow, for they both get away with the coal of the company without compensation. In this case, it would seem that a meter is necessary to correct his conscience.

As to the rates for metered water, they should be adequate to meet the requirements of the works in the city where located. What is just and equitable in one place may be onerous and burdensome in another. A single rate is not proof against trouble, and, as a matter of fact, is not more equitable than the graduated rate. The one rate may be fixed at what seems a safe basis. Then comes a time of depression in business which forces economies in every way, and the water department comes in for a reduction of its revenue by reason of the decrease in the demand for water, so that the revenue will not pay interest and operating expenses. The deficit must be met by raising rates or increasing taxes, to which there would be serious objection on the part of the people. Often the raising of the rate, or increasing taxes, means loss of power by the political party in control.

There is less office work in a single rate, but the graduated scale saves the department from embarrassment and loss, and is safer as a business proposition than the single rate. The single rate may be more popular, but it does not save the department from trouble. If you tax your memories, you will recall that the single rate is often shaded for large consumers, notwithstanding the fact that it is intended to be alike to all. When the shaded rate becomes known, then there is trouble. Objections are made to giving a lower rate to manufacturers using a large quantity of water. The graduated scale permits furnishing them water at a rate based upon the quantity used, and it is not a violation of the rules of the department governing rates, and is in accord with the business methods of the country. A man who puts forth energy and skill is entitled to recognition of his ability. Without some incentive, the best results are not obtainable. A man who establishes a business and becomes a large consumer

of water is entitled to have the water furnished at the lowest possible rate that is fair to the water works, for the reason that his establishment adds value to the city and he becomes a large tax-payer and a supporter of a large number of people by furnishing them employment.

Often at the one low meter rate, the earnings of many of the meters are not equal to the cost of reading the meter, let alone paying interest and the maintenance of the meter.

A reasonable frontage tax is justifiable upon property along a street in which a new main has been laid until there is sufficient business developed on the main to prevent a loss to the city. In the case of a private company, the city pays the company a hydrant rental which covers all the water used for fires and the flushing of sewers. It is generally supposed that the hydrant rental is an expense to the city not reimbursed, but the taxes paid by the water company on its mains and hydrants, and the taxes paid by the people who were induced to build houses on the street by reason of the laying of the main, constitutes a permanent source of revenue to the city, which usually exceeds the amount paid for hydrant rental, besides adding to the value of the property along the street in which the main is laid.

Frontage tax can be imposed by the city, and is a means of obtaining revenue that a private company cannot avail itself of. In the case of the city, if the revenue is not sufficient, the tax-payers are obliged to keep on maintaining the works and paying the interest upon the bonds issued to build the works. The bonds and stock of a private company are often held by estates, retired business men, orphans, trust companies, and savings banks. Therefore, the company should not, under any circumstances, make rates that would not at all times and under all circumstances furnish sufficient money to maintain the water works, pay interest upon the bonds and a reasonable dividend to the stockholders. By so doing it gives stability to its securities.

Meter rates should be graduated so as not to furnish more water for less money or induce a waste, in view of the constantly increasing cost of water, made so by expensive filtration systems, getting water from a greater distance, and the storing of water which is made necessary by the water's continually growing

scarcer. To me it does not seem like a reasonable business proposition to make the same rate for 100 as for 1 000 000 gallons. If the one rate is made too high, then the department does not get the business; if too low, it is equally unfortunate. I do not know of any water works that does not recognize the principle in a flat-rate schedule by selling the second bath or closet at less than the first. If this is right in a flat-rate schedule, why not in a meter schedule?

Mr. W. C. Hawley.* I think we must all recognize that this report is a step in the right direction, and one which will be of benefit to a great many water plants. I do not, however, want to leave it in the position of its being the unanimous opinion of those present that this is a principle which will apply in all cases, and that the rates computed in the cases cited — 5 cents to 15 cents per thousand gallons — are rates at which our private companies should be selling water. As a rule the rates which private companies can charge are fixed in their franchises, and it is an absolute impossibility to change them in accordance with any suggested schedule, however desirable that schedule may be. This report enunciates a principle which can be followed by many municipalities, but it cannot be followed by more than a very few private water companies.

There is one matter which occurs to me in connection with this report regarding the assessment on frontage. That is probably a very equitable way of getting at it in a small town. But in these days of skyscrapers and apartment houses, I think that the height of the building should enter into the assessment, especially in the larger places.

This matter of a uniform rate is simply a question of wholesale and retail business. You cannot draw the line too finely, and undoubtedly a flat rate is the proper thing in a majority of the smaller places; but any water works man knows that it costs more money so sell ten million gallons, we will say, in a year through one thousand meters than it does to sell ten million gallons to half a dozen consumers through half a dozen meters. There is the care and maintenance of the meters, the bookkeeping and reading and all that sort of thing entering into it, and it is a

* General Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

question of the cost. You cannot make a uniform price any more than the storekeeper can put his calico and his silk at a uniform price.

The opposition to meters, in my experience, comes from two sources,— ignorance and politics. Once in a while we get a combination of the two, as we have recently in a western Pennsylvania city, in which the ignorant politician has made an exhibition of himself which I think surpasses anything which has ever been seen in this country previously. But once the meter system has been introduced and people have become used to it, it would be many times more difficult to take the meters out, and go back to the fixture rate, than it was to introduce the meters in the first place.

One gentleman in discussing the report, as I understood him, expressed the idea that no difference should be made between the uses to which the water should be put. My experience is that you must make a sharp distinction between the water that is used for fire protection and that used for other purposes, especially in the smaller classes of mills, such as those which do not come under the Factory Mutual Insurance Companies. They will want a 4- or a 6-inch service where a 2-inch or a 3-inch would be ample, and they will want to attach their sprinkler system to it and fire hydrants, and they won't expect to pay you a cent for the fire protection which is afforded unless they should use the water, and then they want it at the low meter rate. Our company to-day is making a distinction in its contracts. We prohibit absolutely the use of any water for fire protection under a domestic or manufacturing contract, and require a separate contract and a separate service for fire protection. I think that is a principle which is just and right. There is a cost for fire protection service which does not enter into the supplying of water for domestic or manufacturing purposes, but which is distinct and separate from it, and the private company or municipality is entitled to payment for that.

Mr. Robert J. Thomas.* Of course in New England our conditions may be somewhat different from what they are with the private companies in the West in the matter of not being taxed directly, but superintendents of water works in New

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* Superintendent of Water Works, Lowell, Mass.

England know that they are taxed in an indirect manner, at least, — that is, a considerable portion of their revenue has been taken away. In some cities the municipal water works have to furnish free water to the schools, public buildings, fire department, and to the park department. So in that way we are being taxed indirectly and we have to allow for that in making our rates.

In the matter of a sliding scale, our water boards have had to take into consideration that there are manufacturers in our New England cities who, if they did not get water at a certain price, — that is, at the lower scale, — would put in their own water works. In that way they are really depriving the water department of its proper revenue, and are postponing still further the time when the city can reduce the rates for all takers.

So we look at it from different standpoints. Mr. McLean of Holyoke thinks we ought to have a flat rate. Down in the eastern part of Massachusetts we think that the sliding scale is the thing and that we ought to cater to some extent to the manufacturers in order to induce them to become customers of the water department, that our revenue may be thereby increased, and that we may be able in that way to sooner reduce the charge to the small consumers. So you see that even among municipal water works' officials, even in the state of Massachusetts, there is a difference of opinion on these matters.

Mr. Frank C. Kimball.* I have to do almost wholly with private corporations, and I have dealt with such corporations not only in New England but in the South and the West. The committee in presenting their report have given us, I think, some very valuable suggestions to consider. In several instances where it has fallen to me as a part of my duty to prepare schedules I have run across a number of difficulties, as undoubtedly the committee have — as is somewhat shown in their report — and which have been referred to by members here to-day. For instance, in the matter of a minimum rate, I think it goes without saying that a minimum rate is an absolute necessity. Even Milwaukee, which boasts of having no minimum rate, does really have one under the guise of a charge for reading meters, although to be sure it is a

* Civil Engineer, Boston, Mass.

low one. And the point which was brought out, I think, by Professor Bemis, that Milwaukee also requires all their 6-inch mains to be paid for by the abutting property, is a charge equivalent to a minimum rate in itself. Of course private companies cannot do that, but still as he has asked for experiences along that line, I will say that one company I have had to do with has in effect done the same thing in this way: In developing land, when, to bring it into the market to sell to good advantage it has been necessary to have water mains and a water supply, the company has laid such mains entirely at the expense of the owners of the land, but under a contract whereby those mains, of course, belong to and are under the control of the water company; the company on their part agreeing to pay back to the owners of the land from one half to two thirds of all the revenue received from the sale of water from those pipes until they receive in return all that they have advanced. That is one way that private companies can get a part of this money, or at least be sure of a revenue from their investment. Still they do, of course, labor under greater disadvantages than do municipal corporations.

The question of a minimum rate based, as I understand it is at Cleveland and at some other places, on the fixtures in a house, hardly appeals to me from the fact that one advantage of a meter is that it does away with the annoyance of house-to-house inspection. People as a rule dislike to see a water-works inspector rummaging about their houses, in their closets and bath rooms and other places, to see what fixtures they have got. Adopt a minimum based upon fixture rates and you still have to make house-to-house inspections, possibly not to the extent that it is done when rates are based upon fixtures solely, but nevertheless it has to be carried on to a considerable extent. A minimum of a stated amount, without regard to the value of the property or the fixtures in it, must either be fixed so high that you cannot meter the small consumers or it will make the cost of the water prohibitive to them; so that at the first glance, it seems as though the committee in its report had hit somewhere near the right solution of the problem in some of its phases.

On the other hand, a minimum based upon frontage will not work equitably in all cases. Take it in a large city, houses and

flats, occupying perhaps 20 to 25 feet frontage, will not begin to pay the minimum rate of a small 4 to 6-room house in the outskirts, which might occupy and therefore pay on a 50-foot lot, while from their value and use of water such flats should pay a higher rate. Whether or not a minimum could be established that would do away with house-to-house inspection, based perhaps upon frontage plus height, or upon some method of valuation, I do not know. I think it is a question that could well be referred back to the committee in the light of the various experiences that have been given here.

Now, as to the question of rates, wholesale and retail, it seems to me that this is a logical way to sell water, and for this reason: The first cost of delivering water is the greatest, and the use of a maximum of 100 gallons a day, by one party, costs as much within certain limits to supply as to supply the same quantity to a person using 1 000 or 2 000 gallons a day. Of course when you get to a certain point where you have to enlarge your mains, that brings it under another classification. But in making out new schedules of rates it has always appeared to me that the fairest way to make meter rates is to charge for the first quantity of water, whatever it is, say 10 000 or 50 000 gallons a month, a stated price regardless of the ultimate quantity used. For the next quantity of water charge a lower price, and perhaps for a third and fourth larger quantity, getting up into the amounts that large mills would use, much lower prices. There is no question, then, of paying more for a lesser quantity than you do for a greater quantity. Every one pays an equal amount for the first quantity used, and it recognizes the principle that the supply of that first quantity costs just as much for one as it does for another. Then there is a point where within certain limits the only additional cost is the expense of pumping and perhaps purifying additional water, until the time that you have to lay larger mains; and you can afford to sell that excess at a much less price and still make a good profit on it. For that reason, and for the sake not only of encouraging manufacturers to use your water but to keep them from putting in supplies of their own, I think a sliding schedule on that basis is eminently proper.

MR. KENNETH ALLEN* (*by letter*). The committee's plan of a rate for water based both upon frontage and consumption appears reasonable and practicable. To devise a scheme that will be equitable in all cases seems to be as difficult as to find a practicable method of assessing for sewers and paving that will meet with universal approval, and we can only adopt that method which, while approximately fair to all, is at the same time not too cumbrous to put into practice.

One difficulty that would be avoided by the proposed plan is the fixing of a proper minimum rate. In the writer's opinion the minimum rate should, where used, represent the items — such as actual cost to the water department for installation and maintenance of service — for which the frontage rate is provided. Now, this is frequently a small sum in comparison with the value of water used, and if the minimum rate charged is much in excess of this amount the true value of the meter system is to that extent lost. In other words, the *ordinary* charge for water should be in excess of the minimum rate instead of the reverse, and the meter rate so adjusted as to provide the required revenue.

[On motion of Mr. Charles W. Sherman it was voted that the report of the committee be accepted and the committee continued.]

* Engineer and Superintendent of Water Works, Atlantic City, N. J.

PROCEEDINGS.

June Meeting.

Attleboro, Mass., June 28, 1905.

The June meeting of the Association was held at Attleboro, Mass., on Wednesday, the 28th inst., with an attendance of one hundred and fifty-three members and guests, as follows:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, J. E. Beals, F. D. Berry, J. F. Bigelow, J. M. Birmingham, George Bowers, C. L. Bowker, G. A. P. Bucknam, J. Burnie, L. Z. Carpenter, S. K. Clapp, L. P. Collins, M. F. Collins, M. J. Doyle, J. W. Ellis, W. E. Foss, F. L. Fuller, W. B. Fuller, H. F. Gibbs, J. C. Gilbert, A. S. Glover, J. A. Gould, J. O. Hall, W. D. Hubbard, J. W. Kay, W. Kent, G. A. King, W. F. Learned, J. W. Locke, A. A. Knudson, T. H. McKenzie, H. McLean, H. V. Macksey, D. A. Makepeace, W. E. Maybury, J. Mayo, F. E. Merrill, C. A. Mixer, F. L. Northrop, J. W. Smith, G. H. Snell, G. A. Stacy, J. T. Stevens, W. F. Sullivan, L. A. Taylor, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, C. K. Walker, J. C. Whitney, W. P. Whittemore, L. J. Wilber, I. S. Wood, F. I. Winslow, G. E. Winslow, H. D. Woods. — 59.

Associates.

Ashton Valve Co., by C. W. Houghton; Harold L. Bond & Co., by Harold L. Bond; Henry A. Depser; Builders Iron Foundry, by F. N. Connet and A. B. Coulters; Coffin Valve Co., by H. L. Weston; Fred C. Gifford; Hersey Mfg. Co., by Albert S. Glover and Walter A. Hersey; Jenkins Bros., by R. H. Stiles; Lead Lined Iron Pipe Co., by T. E. Dwyer; H. Mueller Mfg. Co., by W. L. Diekel and O. B. Mueller; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Rensselaer Mfg. Co., by F. S. Bates and C. L. Brown; Platt Iron Works Co., by F. H. Hayes; A. P. Smith Mfg. Co., by F. N. Whitcomb; Sweet & Doyle Valve Co., by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop and W. F. Hogan; R. D. Wood & Co., by Wm. F. Woodburn. — 24.

Guests.

A. N. French, Supt., Hyde Park Water Co., Hyde Park, Mass.; John Kelley, Comr., and Mrs. W. E. Maybury, Braintree, Mass.; Mr. and Mrs. Walter Phillips, Weymouth, Mass.; Mr. G. W. Strandberg, Chas. McConnell James A. McKenna, Providence, R. I.; Elisha T. Jenks, H. W. Sears, A.

G. Hayes, Mr. Amos H. Eaton, Walter A. Beals, Middleboro Mass.; George A. Carpenter, Pawtucket, R. I.; Arthur C. King, Taunton, Mass.; A. L. Mixer, Rumford Falls, Me.; D. Kingman, H. H. Chase, Brockton, Mass.; N. B. Tower, Cohasset, Mass.; Andrew R. McCallum, Whitman, Mass.; I. C. Sears, E. A. Baxter, Hyannis, Mass.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. Frederic I. Winslow, George W. Blodgett, Mr. and Mrs. E. S. Dorr, Katharine T. McCarthy, E. F. Clasby, Boston, Mass.; C. A. Peirce, Syracuse, N. Y.; W. H. Van Winkle, New York City; Mrs. Wm. F. Woodburn, Philadelphia, Pa.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. H. D. Woods, West Newton, Mass.; Mrs. George Bowers, Miss Helen E. Bowers, Lowell, Mass.; Mr. F. A. Leavitt, Malden, Mass.; B. Dwyer, Hartford, Conn.; Mrs. L. J. Wilbur, Brockton, Mass.; Mrs. H. A. Desper, Worcester, Mass.; L. P. Stone, Natick, Mass.; Mr. L. M. Hudson, Thomas Burke, Marlboro, Mass.; W. H. Day, Milford, Mass.; George H. Palmer, Wm. H. Goff, E. S. Horton, Peter Nemay, H. D. Baker, Caleb Slade, Willard A. Eugley, Alberta Remington, C. S. Holden, H. S. Robinson, E. O. Dexter, A. M. Briggs, J. F. Makinson, W. B. Ballou, Annie A. Wheeler, G. H. Sykes, Winthrop F. Barden, J. A. Welsh, C. C. Cain, Carrie L. Perry, S. M. Holman, H. E. Claf, E. J. Ivarmstrom, W. W. Stone, W. N. Goff, G. A. Sweeney, H. R. Packard, Edgar Tregoning, Attleboro, Mass., and Samuel Harrison, of the H. R. Worthington Co. — 73.

[Names counted twice — 3.]

Special cars were attached to the regular train from Boston arriving in Attleboro at ten o'clock, where the party was met by the water commissioners of the town, and entertained as their guests during the day.

Automobiles were in waiting at the railroad station, and in these the party was quickly conveyed to the summit of Ides Hill, where an opportunity was afforded to inspect the reinforced concrete standpipe in process of construction, and incidentally much of the surrounding country, to the enjoyment of which the unusual clearness of the atmosphere materially contributed.

The work inspected includes a new well at the source of supply, constructed last year, and a reinforced concrete standpipe, now under construction.

The new well from which ground water is taken is situated on the banks of the Seven Mile River and is 40 feet in diameter and about 25 feet deep. The well is covered with a Guastavino tile roof.

To provide the necesary storage so that the pump run may be limited to the day hours a standpipe 50 feet in diameter and 100

feet high, of about 1 500 000 gallons capacity, is being constructed. It is situated on Ides Hill at an elevation of 252 feet above mean tide.

The walls are to be of concrete, mixed one part cement, two parts sand, and four parts crushed stone, particular care being taken in the grading of the aggregate, so as to reduce the voids to a minimum. The walls are to be 18 inches thick at the bottom and 8 inches at the top. Movable wooden forms in sections are used in placing the concrete in walls.

The interior surface is to be plastered with a mortar composed of cement, sand, glue, and alum, one-half inch thick, troweled to a granolithic finish.

The horizontal reinforcement is by circular steel bars, ranging in size from $1\frac{1}{8}$ to $1\frac{1}{2}$ inches diameter, spaced as made necessary by the pressure at different elevations. The vertical bars are of twisted steel $\frac{3}{8}$-inch diameter staggered so as to permit the wiring of horizontal bars to them.

The standpipe is to be roofed by a Guastavino tile dome and is to be capped by a heavy concrete cornice.

The pump wells and station were visited, and a ride through the country thoroughly enjoyed. On the return to the village lunch was served, followed by a visit to some of the noted jewelry manufactories.

Immediately following lunch a brief business meeting was held.

Twelve applications for membership, recommended by the Executive Committee, were presented, and by vote of the Association the following-named applicants were elected members:

Luis Matamoros, Municipal Engineer, San José, Costa Rica; Charles H. Campbell, Superintendent of Water Works, Charlotte, N. C.; William W. Locke, Sanitary Inspector, Metropolitan Water and Sewerage Board, South Framingham, Mass.; Theodore A. Leisen, Chief Engineer, Water Department, Wilmington, Del.; Wallace Greenalch, Superintendent Bureau of Water, Albany, N. Y.; James M. Caird, Chemist and Bacteriologist, Troy, N. Y.; Charles M. Bolton, Superintendent of Water Works, Olympia, Wash.; Ralph Howard Garrison, Superintendent of Water Works, Sewerage System and Electric Light Plant, Vineland, N. J.; Arthur N. French, Hyde Park, Mass.; Alexander Macphail, Professor of General Engineering, Queens University, Kingston, Ont.; Clyde Potts, Sanitary Engineer,

New York City; George H. Felix, General Manager of Water Department, Reading, Pa.

The thanks of the Association were tendered by rising vote to the water commissioners and citizens of Attleboro for the courtesies which had rendered the day so enjoyable.

Mr. Snell responded in behalf of the commissioners, and Mr. J. Waldo Smith of the New York Committee on Annual Convention gave an interesting address on the plans of the committee and the arrangements being made for the meeting.

The President announced that the Annual Convention would be held in New York on the 13th, 14th, 15th and 16th of September.

WILLARD KENT, *Secretary*.

TWENTY-FOURTH ANNUAL CONVENTION.

NEW YORK CITY, September 13, 14, 15, 1905.

The Twenty-Fourth Annual Convention of the New England Water Works Association was held at New York City, on Wednesday, Thursday, and Friday, September 13, 14, and 15, 1905. The headquarters of the Association during the convention were at the Murray Hill Hotel, and the meetings were held there.

The following members and guests were registered:

MEMBERS.

S. A. Agnew, K. Allen, M. N. Baker, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. B. Bassett, G. W. Batchelder, J. E. Beals, E. W. Bemis, F. D. Berry, C. R. Bettes, J. M. Betton, J. F. Bigelow, J. M. Birmingham, F. E. Bisbee, G. H. Bishop, G. Bowers, E. C. Brooks, W. W. Brush, J. Burnie, C. E. Chandler, S. K. Clapp, H. W. Clark, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, V. R. Connor, J. H. Cook, G. K. Crandall, A. W. Cuddeback, L. B. Cummings, F. A. W. Davis, J. M. Davis, M. J. Doyle, J. Doyle, E. R. Dyer, H. D. Eaton, E. D. Eldredge, J. W. Ellis, E. A. Ellsworth, E. A. Fisher, A. D. Flinn, R. J. Flinn, J. H. Flynn, A. A. Fobes, M. Forbes, E. H. Foster, G. H. Felix, J. R. Freeman, E. V. French, F. L. Fuller, G. W. Fuller, W. B. Fuller, S. DeM. Gage, E. W. Gaylord, W. P. Gerhard, W. B. Gerrish, D. H. Gilderson, A. S. Glover, R. H. Garrison, W. J. Goldthwait, X. H. Goodnough, F. W. Gow, E. H. Gowing, J. W. Graham, J. W. Griffin, C. A. Hague, A. S. Hall, J. C. Hammond, Jr., L. P. Hapgood, G. W. Hawkes, W. E. Hawks, W. C. Hawley, T. G. Hazard, Jr., A. Hazen, D. A. Heffernan, C. Herschel, W. R. Hill, H. G. Holden, F. S. Hollis, G. S.

Hook, J. A. Huntington, J. H. Ince, G. I. Ingersoll, D. D. Jackson, H. R. Johnson, W. E. Johnson, W. S. Johnson, A. J. Jones, J. W. Kay, E. W. Kent, W. Kent, P. Kieran, F. C. Kimball, G. A. King, T. A. Leisen, A. A. Knudson, M. Knowles, E. S. Larned, E. E. Lochridge, M. O. Leighton, H. A. Lord, F. H. Luce, C. M. Lunt, J. W. Lynch, D. B. McCarthy, S. H. McKenzie, T. H. McKenzie, Thomas McKenzie, Hugh McLean, D. E. Makepeace, W. M. Marple, W. P. Mason, W. E. Maybury, F. E. Merrill, D. S. Merritt, P. S. Miller, F. F. Moore, J. W. Moran, J. F. J. Mulhall, F. L. Northrop, E. L. Nuebling, O. E. Parks, C. L. Parmelee, D. H. Parsons, W. Paulison, E. M. Peck, E. L. Peene, E. B. Phelps, F. H. Pitcher, F. V. Pitney, A. Potter, G. S. Rice, W. H. Richards, T. F. Richardson, W. W. Robertson, G. A. Sanborn, W. J. Sando, W. H. Sears, E. M. Shedd, C. W. Sherman, M. R. Sherrerd, M. A. Sinclair, J. W. Smith, G. H. Snell, G. A. Soper, H. T. Sparks, J. F. Sprenkel, G. A. Stacy, J. T. Stevens, W. F. Sullivan, G. A. Taber, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, L. L. Tribus, A. S. Tuttle, W. Volkhardt, E. L. Wallace, C. S. Warde, J. S. Warde, R. S. Weston, W. J. Wetherbee, G. C. Whipple, J. C. Whitney, W. P. Whittemore, L. J. Wilber, F. I. Winslow, G. E. Winslow, E. T. Wiswall, Timothy Woodruff, G. W. Wright, W. S. Wyman, W. G. Zick. — 178.

Honorary Members.

J. J. R. Croes, F. W. Shepperd. — 2.

Associates.

Allis-Chalmers Co., by F. D. Herbert, Arthur Warren, G. H. Berg, J. E. Lord, W. J. Sando, Timothy Lynch, P. C. Gibson, and C. G. Wingate; Ashton Valve Co., by C. W. Houghton; Roy S. Barker; Builders Iron Foundry, by A. B. Coulters; Coffin Valve Co., by H. L. Weston; Henry A. Desper; M. J. Drummond by John Amstadter and Walter S. Drummond; The Fairbanks Co., by F. A. Leavitt, C. O. Churchill, J. F. O'Brien, S. P. Cates, and Chas. H. White; Garlock Packing Co., by G. R. Noble, L. Bulkley, and J. E. Case; Fred C. Gifford; Hays Mfg. Co., by T. J. Nagle and R. C. French; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, F. A. Smith, W. A. Hersey, and W. C. Sherwood; International Steam Pump Co., by J. D. A. Silva, W. F. Flynn, Sam'l Harrison, H. F. Peake, and E. F. Walker; Jenkins Bros., by J. F. Stiles and C. F. Webber; Kennedy Valve Co., by M. J. Brosnan and J. F. Morgan; Lead Lined Iron Pipe Co., by T. E. Dwyer and W. Lockwood; Ludlow Valve Co., by H. F. Gould; H. Mueller Mfg. Co., by T. F. Leary, Warren Hason, A. C. Pilcher, O. B. Mueller; National Meter Co., by John C. Kelley, C. H. Baldwin, J. C. Kelley, Jr., Fred S. King, W. P. Oliver, J. G. Lufkin; Neptune Meter Co., by C. A. Vaughan, T. D. Faulks, H. H. Kinsey, J. L. Wertz, Mr. Gammon; New York Continental Jewell Filtration Co., by R. E. Milligan; Pittsburg Meter Co., by T. C. Clifford and V. E. Arnold; The Platt Iron Works Co., by F. H. Hayes; Rensselaer Mfg. Co., by F. S. Bates, C. L. Brown, and J. S. Warde, Jr.; Ross Valve Co., by William Ross and Adam

Ross; Central Foundry Co., by Mark Dean and E. A. Scott; A. P. Smith Mfg. Co., by A. P. Smith, D. F. O'Brien, F. N. Whitcomb, and J. W. Strackbeim; Thomson Meter Co., by E. J. Snow, S. D. Higley, H. G. Folger, and J. C. Wilshin; Union Water Meter Co., by F. L. Northrop, W. F. Hogan, L. P. Anderson, E. F. King; U. S. Cast Iron Pipe and Foundry Co., by R. W. Martindale, Nathaniel Miles, W. B. Franklin, and H. H. Putnam; R. D. Wood & Co., by Wm. F. Woodburn and A. T. Prentice. — 87.

Guests.

Mrs. George E. Winslow, Mrs. F. C. Gifford, Mr. and Mrs. E. Earle Gifford, Minnie A. Gifford, Maud Durgin, Waltham, Mass.; Mrs. F. L. Fuller, Wellesley Hills, Mass.; Mrs. George A. Sanborn, Julia N. Collins, A. A. Schaake, Lawrence, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. Wm. H. Thomas, Hingham, Mass.; Edwin Leavitt, Lillian E. Leavitt, Mrs. Edward W. Shedd, Somerville, Mass.; Mr. and Mrs. A. W. Danforth, Lucy A. Danforth, Susette C. Berry, Mrs. L. M. Bancroft, Reading, Mass.; M. C. Damon, Wm. E. Lothrop, Leominster, Mass.; Mrs. J. Wm. Kay, Milford, Mass.; Mrs. L. J. Wilber, Campello, Mass.; Mary S. Goldthwait, Eleanor R. Goldthwait, Marblehead, Mass.; Mrs. John Doyle, Mrs. H. A. Desper, Charles F. Merrill, Worcester, Mass.; Mr. and Mrs. W. E. Hatch, Mrs. R. J. Thomas, Mrs. George Bowers, Miss Helen Bowers, Mrs. E. H. Scribner, Mr. and Mrs. I. E. Wotton, Mr. and Mrs. Z. W. Sturtevant, Lowell, Mass.; Mrs. E. L. Wallace, Franklin Falls, N. H.; Mrs. E. A. Ellsworth, Alice S. Corner, Mrs. M. J. Doyle, Mary Buckley, Miss Nellie Curran, George O. Connell, Holyoke, Mass.; George A. Wooley, Joan M. Ham, Margaret G. Flinn, Mrs. G. R. Noble, Mrs. Frank C. Kimball, George F. Hiller, Mrs. H. F. Gould, W. O. Weaver, Charles S. Shaughnessey, T. W. Norcross, Boston, Mass.; Winifred L. McGowan, No. Attleboro, Mass.; Elizabeth V. McDermott, Roxbury, Mass.; Mrs. D. A. Heffernan, Milton, Mass.; Mrs. D. E. Makepeace, Attleboro, Mass.; Mrs. E. C. Brooks, Mr. and Mrs. J. P. Bacon, Cambridge, Mass.; Everett I. Bray, M. J. McLaughlin, Gloucester, Mass.; J. J. McNally, Mr. and Mrs. G. M. McKelvey, Mr. and Mrs. H. M. Garlick, Mr. and Mrs. H. W. Heedy, Youngstown, O.; Mrs. W. E. Maybury, Braintree, Mass.; Mrs. Murray Forbes, Morton W. Crownover, Ass't Supt., and Paul L. Yount, Ass't Supt., Greensburg, Pa.; Mrs. C. A. Vaughan, Mrs. T. D. Faulks, Mrs. J. F. O'Brien, Wm. S. Crandall, Editor "Municipal News," Mr. and Mrs. W. H. Van Winkle, Mr. and Mrs. C. Van Houtten, Mrs. Allen Hazen, W. H. Fitch, Mrs. Alfred D. Flinn, Mr. and Mrs. Henry B. Machen, Dr. Henry T. Coggeshall, Mr. and Mrs. Thos. J. Gannon, Mrs. J. C. Hanlon, Edward L. Walker, John P. Reynolds, Jr., Mrs. George A. Taber, W. F. Stodder, Mrs. G. C. Whipple, Mrs. George W. Fuller, W. H. Van Winkle, Jr., Pierre Pullis, F. M. Griswold, G. E. Bruen, Mrs. Alexander Potter, John S. Hodgson, Editor "Municipal Journal," S. T. Henry, Asso. Editor "Engineering Record," Ant. Breneman, Myron S. Falk, Mary R. Clapp, Edward Nuebling, Jacob Thoma, Glen Marston, "Engineering News," C. W. DuB. Gould, W. B. Goentner, Miss Ella Ringelman, Mrs. H. B. Brougham,

Mrs. F. W. Shepperd, George H. Benton, T. S. McNally, R. S. Prindle, J. B. Newhall, Dr. and Mrs. J. O. Taylor, Miss A. G. Ambrose, Mrs. T. Freedman, Edward H. Babcock, Miss M. Mansfield, Mrs. K. T. Todd, Mrs. Frank Gascoigne, E. J. Buttenberm, "Municipal Journal," Mrs. F. S. Bulkley, A. E. Van Gieson, Raymond L. O'Brien, R. E. S. Geare, Frank Martin, Miss Elizabeth Pratt, Irving C. Bull, G. Everett Hill, Andrew Mayer, Jr., and Mrs. Fred F. Moore, New York City; Mrs. Washington Paulison, C. A. Terhune, Walter C. Hopper, Passaic, N. J.; Miss Eliza Codd, Nantucket, Mass.; Mrs. C. O. Churchill, Charles Davis, Mrs. Wm. F. Woodburn, Miss V. M. Rondeau, Springfield, Mass.; Mrs. W. E. Hawks, Bennington, Vt.; Mrs. J. M. Davis, Rutland, Vt., Dr. John B. Wheeler, Dr. and Mrs. F. E. Clark, George Q. Stone, J. E. Meagher, Burlington, Vt.; Mrs. Fred S. Bates, W. P. Mason, Jr., Troy, N. Y.; Mrs. E. W. Small, Portland, Me.; Mrs. George K. Crandall, Mrs. W. H. Richards, New London, Conn., Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. Edward L. Peene, R. W. Bogart, Jr., C. DeA. Bogart, Miss Susan M. Gould, Jos. F. LeCount, Yonkers, N. Y.; Mrs. J. H. Cook, Paterson, N. J.; Dr. John T. Collins, Whitman, Mass.; Mr. and Mrs. Thos. S. Peirce, Mrs. J. W. Vaughan, East Greenwich, R. I.; John M. Bancroft, Bloomfield, N. J.; Miss May I. Agnew, W. D. Agnew, Mrs. M. McConkey, Mrs. R. A. Nimmo, A. Kitteredge, Jersey City, N. J.; Mrs. D. H. Gilderson, Haverhill, Mass.; Mrs. W. J. Sando, Milwaukee, Wis.; Mrs. G. A. Trowbridge, West Newton, Mass.; Wm. O. Devoll, Wm. H. Pitman, Louis H. Richardson, New Bedford, Mass.; George W. Stevens, South Braintree, Mass.; R. Henry Jones, Supt., Norfolk, Va.; Mrs. George H. Felix, Mr. and Mrs. S. H. Close, Mr. and Mrs. M. Haabster, Mr. and Mrs. F. P. Heller, Edw. Elbert, Reading, Pa.; Mrs. J. F. Bigelow, Mr. and Mrs. Chas. H. Andrews, Mrs. George A. Stacy, Mr. and Mrs. F. A. McGill, Mr. Con. Flynn, Miss Flynn, E. S. Murphy, Frank Murphy, Marlboro, Mass.; Mrs. H. A. Lord, Ogdensburg, N. Y.; C. L. Beach, Mrs. Roy S. Barker, Miss Grace Anderson, Providence, R. I.; H. A. Holmes, Mrs. D. B. McCarthy, Miss Nellie Esmond, Waterford, N. Y.; Alex Orr, C. E., Supt., Gloversville, N. Y.; Olin H. Landreth, Prof. Union College, George Holtzmann, Schenectady, N. Y.; J. D. Landis, Mechanicsburg, Pa.; A. A. Reimer, Mrs. Mark Dean, F. A. Reimer, W. H. V. Reimer, Hon. Wm. Cardwell, F. Lardley, J. M. Brown, A. W. Baigrie, F. J. Greer, Mr. and Mrs. Daniel C. Osmun, E. S. Perry, J. N. Travis, Orange, N. J.; C. J. Barrett, South Orange, N. J.; F. A. O'Conner, West Orange, N. J.; Mr. and Mrs. J. M. Kinder, Meriden, Conn.; Perry T. W. Hale, Jas. Lawton, P. C. Denehy, Middletown, Conn.; Bartholomew Dwyer, James Orr, Southington, Conn., Miss Florence Serrell, North Plainfield, N. J.; Benj. I. Drake, Plainfield, N. J.; Mrs. W. C. Hawley, Harold A. Allen, Atlantic City, N. J.; Mr. and Mrs. C. D. Pollock, Mr. and Mrs. Sam'l F. Thomson, Miss Elizabeth Thomson, Mrs. Wm. R. Hill, Miss Alice Hill, Frank E. Connolly, Mrs. H. M. Mills, Mrs. C. C. Mulford, Alice C. Flinn, Thomas F. Flinn, Mrs. E. W. Keese, Miss S. A. Cross, Wm. R. Fleming, John F. Mead, Brooklyn, N. Y.; Mrs. W. B. Gerrish, Oberlin, Ohio; Mr. and Mrs. L. W. Anderson, Grand Rapids, Mich.; A. M. Campbell, Mrs. J. S. Warde, West

New Brighton, N. Y.; Mrs. J. D. Landes, Mechanicsburg, Pa.; Mrs. E. D. Eldredge, Onset, Mass.; Beekman C. Little, Rochester, N. Y.; George T. Cullen, John W. Murphy, John J. Creedon, Malden, Mass.; Mr. and Mrs. Richard Veale, Kearney, N. J.; Mrs. W. B. Fuller, Pittsburg, Pa.; Frank M. Collins, Walden, N. Y.; Edward B. Hiding, Chicago, Ill.; Charles P. Brightman, J. W. Milne, Mrs. Patrick Kieran, Fall River, Mass.; Miss Eva Brown, Miss Mattie Calhoun, Miss Emma Savage, Indian Orchard, Mass.; Mrs. F. H. Luce, Woodhaven, N. Y.; Chas. N. Oakes, Frank S. Dewey, Jr., Henry W. Sanderson, J. H. Packard, S. W. Hildreth, Westfield, Mass.; M. Otagawa, Tokio, Japan; J. Ralph Duyne, John E. Hill, Newark, N. J.; E. Frailey, W. H. Frailey, Lancaster, Pa.; Mrs. Charles R. Bettes, Far Rockaway, N. Y.; Charles R. Tucker, Staten Island, N. Y.; H. Dallas McCabe, Monessen, Pa.; Joseph E. Carroll, Lowell, Mass.; J. A. Nelson, Pittsburg, Pa.; Mrs. John F. J. Mulhall, Boston, Mass.; Frank Brigham, Elizabeth, N. J.; F. O. Sinclair, Burlington, Vt.; J. C. Richards, P. A. Maignen, Philadelphia, Pa.; Alfred M. Quick, Baltimore, Md.; Mrs. C. H. White, Jamaica, N. Y.; W. R. Scofield, Matteawan, N. Y.; Miss Capen, Miss Ethel Capen, St. Louis, Mo.; Edwin L. Newcomb, Vineland, N. J.; R. W. Pratt, George A. Johnson, Columbus, Ohio; Karl F. Kellerman, Washington, D. C.; Herbert B. Baldwin, Newark, N. J.; C. Arthur Brown, Lorain, Ohio; F. W. Green, Little Falls, N. Y.; John F. Gallagher, Kingston, N. Y.; Moses Joy, Milford, Conn.; W. D. Horne, Yonkers, N. Y. — 314.

Summary of attendance: Members, 178; Honorary Members, 2; Representatives of Associates, 87; Guests, 314; counted twice, 4; total, 577.

Wednesday, September 13.

The convention was called to order at ten o'clock by President George Bowers, and Mr. J. Waldo Smith, Chairman of the Local Committee, was presented. Mr. Smith spoke as follows:

Mr. President and Members of the New England Water Works Association, — It is particularly gratifying to the members of the various committees who have had the arrangements for this convention in charge to see such a large attendance at the opening session. We trust that nothing will interfere with the pleasures or the more serious duties of this gathering; that when you return to your homes it will be with the firm conviction that this has been the best convention ever held by the Association, and that you will have a desire to come here again. It seems particularly fitting that in breaking your custom once more and holding a convention outside of New England, the most influential water works association in the country should come to its largest and most influential city.

A very distinguished gentleman has kindly consented to come here this morning and say a few words on behalf of the city of New York, and I have now the honor to introduce to you, the corporation counsel of the greatest city in the world, the Hon. John J. Delany. [Applause.]

ADDRESS OF WELCOME BY THE HON. JOHN J. DELANY, CORPORATION COUNSEL OF THE CITY OF NEW YORK.

Mr. Chairman, Ladies and Gentlemen, — I regret very much that the mayor, who has just returned from his vacation to take hold of a large amount of deferred work, is unable to be here, because I believe he is the greatest water-works man in the world. He has been the prime agent in bringing about the extension of our water system.

We are now preparing plans for what will be the greatest water works ever known in the history of civilization. Whether in the old civilizations that have passed away, or in the new ones which have come up in these later years, I do not believe there have been any water works that will compare, when they are extended according to their general plan and scope, to the water works over which Mr. J. Waldo Smith will have the honor to preside, and whose destinies will be left in his keeping. [Applause.]

Gentlemen, you belong to a profession which does not appear in anything like its fullness in the beginning of civilizations. When cities are being formed you are not consulted, but when they grow in wealth and in prosperity, when human endeavor has enlarged the habitations of men around a given spot, when the complexity of human life in closely compacted centers makes it necessary to turn attention to those things which are required for the success of industrial efforts and for the preservation of human health, then the people turn to you with suppliant hands and ask you, like Moses, to be the deliverer of a great people. So you see you are rather distinguished, although perhaps you had not discovered it until this moment. [Applause and laughter.]

And you may also realize that your function in life is one most important. You are not present when a nation or a city is

cradled, nor are you present when a nation or a city goes down to decay, because it is only when it ceases to consult the engineer that a city topples to its ruin. When it would spread out in magnificence and in architectural and mechanical grandeur, then it has to be guided by the mature mind of the engineer.

I am impressed with the fact that you are like the men who brought God's beautiful water in olden times from the top of the mountains, down by devious routes into the valley to the thirsty people below. Now you do even more than that. You see that on its way down it shall not be contaminated, or, at least, if you do not do that, you are resorting to all means and employing all the ingenuity at your command to purify it from all contamination and to furnish an abundance of pure and wholesome water to strengthen the people and to help them along in their work of improvement and progress.

Gentlemen, there is not a place in the world more appropriate for the discussion of the bacteriological and the medical questions, as well as the mechanical problems involved in your great profession, than this great city, teeming with its millions of people, growing with a rapidity that is something marvelous, every year adding the numbers of a large city to its population. You come here to consult one with the other, to bring about the solution of questions which concern very gravely the public health of large communities. Modern bacteriology has pointed out to us that you water-works people are in the main those upon whom we must rely to guard us against that great and terrible affliction which comes so often upon the human race in large centers of population, and which under one name or another in antiquity and in modern times has decimated whole communities. I refer to that great scourge, typhoid fever. You will prescribe when you lay out our water works, and when you provide for their maintenance, such measures as will, if it is possible, prevent contamination by the germs of typhoid fever and kindred diseases. If you cannot prevent the contamination, you will study the problem and endeavor to solve the difficulty by destroying the germs after they get into the water supply. So you see, in your great profession, you are linked with the physician, and with the modern bacteriologist.

And all the time that you are doing your work you are working for two ends: first, the preservation of the health of the people, and second, the promotion of their industrial undertakings.

I welcome you here in behalf of the mayor of our city, who sends his regrets at his enforced absence. We offer you all that there is here for a stranger to see in this, the greatest city in the world, as Mr. Smith has very properly called it. This city is great, not only on account of her position, not only on account of the activity and enterprise of her own citizens, however great that may be, but on account of the coöperation with us of all the people throughout this magnificent land, who rest under the protecting ægis of the Stars and Stripes, our common heritage. And when you are endeavoring to solve these great problems for the preservation of the public health and for the promotion of the prosperity of the people, you are really in the position not merely of lowly workmen in the cause of humanity, but of co-laborers in the important work of the advancement of the human race.

I welcome you again, in my own behalf and on behalf of the mayor, to our great city. Its doors are flung wide open to you, and you can do as you please, because New York is not critical if a man does not put his foot through the penal code. [Laughter.] You may have different views than we have about some things. You may have different ideas than we have here, but we hope that after you have seen us for yourselves you can go back and say to the communities in which you live that you have never seen a large city in the world which is as good and as God-fearing as this great American city of New York. And you can say it justly, in spite of our own hypercriticism, for the lash is laid on our back by no one as hard as we lay it on ourselves, and our great prosperity and the fact that so many problems in modern city life have been solved here is largely due to the impetus which we have given to ourselves by the very criticism which we have so freely bestowed upon ourselves. We are not so bad as we would lead you to believe we are, and we want you to go around among us and find out that we are really the best people in the world. We hope you will make the effort to do so, anyway. [Applause.]

I thank you very much for this opportunity to meet you. I thank you for the attention with which you have heard me, and

as I have to go to another meeting now I will bid you good-morning, wishing you all success. [Applause.]

NEW MEMBERS ELECTED.

The Secretary read the following names of applicants for membership, all of whom had been duly recommended by the Executive Committee:

For Member. — Burt B. Hodgman, Civil Engineer, New York City; Richard W. Bogart, Jr., Hydraulic Engineer, National Board of Fire Underwriters, New York City; C. Arthur Brown, Sanitary Engineer, Lorain, Ohio; W. W. Burnham, Engineering Department, Hugh MacRea Co., Wilmington, N. C.; Frederick W. Carpenter, Assistant Engineer, New York Rapid Transit Com., New York City; Edward A. Clark, Kingston, N. Y.; David N. Cook, Superintendent Water Works, Salem, Mass.; L. W. Dalrymple, City Engineer, Bayonne, N. J.; P. C. Denehy, Assistant Superintendent Middletown Water Works, Middletown, Conn.; Benj. I. Drake, of Drake & Thorp, Plainfield, N. J.; Bartholomew Dwyer, Assistant Superintendent, Hartford Water Works, Hartford, Conn.; J. W. R. Fitzpatrick, Civil and Mechanical Engineer, Cohoes, N. Y.; W. B. Goentner, Assistant Engineer, National Board of Fire Underwriters, New York City; J. W. DuB. Gould, Hydraulic Engineer with National Board of Fire Underwriters, Yonkers, N. Y.; Thomas Joseph Gannon, Mechanical Engineer, with Department of Water Supply, Gas, and Electricity of New York City, Brooklyn, N. Y.; Edward D. Hardy, Superintendent Filtration Plant, Washington, D. C.; Perry T. W. Hale, Superintendent and Engineer Middletown Water Works, Middletown, Conn.; George A. Johnson, Engineer in charge Sewage Testing Station, Columbus, Ohio; R. Henry Jones, Superintendent Water Works, Norfolk, Va.; Charles T. Kavanagh, Water Purveyor, City of Bayonne, N. J.; George G. Kennedy, Superintendent Water Works, Harrisburg, Pa.; Beekman C. Little, Superintendent Water Works, Rochester, N. Y.; James A. Locke, with New York Rapid Transit Commission, White Plains, N. Y.; Henry B. Machen, Assistant Engineer, Rapid Transit Commission, New York City; H. Dallas McCabe, Superintendent Monessen Water Co., Monessen, Pa.; E. H. Nordendahl, Member Committee of 20, National Board of Fire Underwriters, Brooklyn, N. Y.; Theodore W. Norcross, Hydrographic Aid in New England of United States Geological Survey, Medford, Mass.; Edward A. Northey, Chief Inspector with New England Bureau of United Inspection, Salem, Mass.; Geo. H. Palmer, Chief Engineer, Attleboro Pump-

ing Station, Attleboro, Mass.; Thomas T. Peirce, Superintendent and Treasurer, East Greenwich Water Supply Co., East Greenwich, R. I.; Clarence DuBois Pollock, Assistant Engineer of Highways, Brooklyn, N. Y.; Alfred M. Quick, Chief Engineer, Baltimore Water Department, Baltimore, Md.; Arthur A. Reimer, Superintendent East Orange Water Department, East Orange, N. J.; John P. Reynolds, Jr., Mechanical Engineer with Department of Water Supply, New York City; Wm. M. Stone, Chairman of Water Board, Attleboro, Mass.; Jacob Thoma, with Department Water Supply, High Pressure Fire System, New York City; Ernest P. Whitten, Civil Engineer, Stewart Station, Pa.; Charles M. Woodward, Water Commissioner, West Springfield, Mass.

For Associate. — W. H. Fitch, Eastern Manager, Walter Macleod & Co., New York City; Walter H. Van Winkle, General Manager, Water Works Equipment Company, New York City.

By direction of the meeting, on motion of Mr. Fuller, the Secretary cast one ballot in favor of the applicants above named, and they were declared elected.

STANDARD PIPE SPECIFICATIONS.

The President announced the receipt of a communication in regard to Standard Specifications for Cast-Iron Pipe, which he called upon Mr. Sherman to read. The communication was as follows:

NEW YORK CITY, August 30, 1905.

THE NEW ENGLAND WATER WORKS ASSOCIATION,
715 TREMONT TEMPLE, BOSTON:

Gentlemen, — J. J. R. Croes, C. E., Chairman Committee on Standards of the American Water-Works Association, has appointed a conference committee consisting of J. Waldo Smith, C. E., Theo. A. Leisen, C. E., with myself as chairman, and I write to request that you appoint a committee of three to meet with us regarding standard pipe specifications. There will also be represented American Testing Association and the Western Society of Engineers, to whom I am writing to-day with reference to the subject.

Kindly let me hear from you at your early convenience and oblige,

Yours very truly,
(Signed) CHAS. A. HAGUE,
Chairman Conference Committee.

Mr. Charles W. Sherman. A number of years ago this Association appointed a committee on standard specifications for cast-iron pipe, and after about a year's work and extensive discussion of preliminary specifications submitted by the committee, the committee finally reported a set of specifications which was adopted by the Association, and which has been used quite extensively since that time, particularly in New England, with very good success, I think, by those members who have used it, — certainly by those in the large communities who have been buying pipe in sufficiently large quantities. There has been some feeling that we have done enough in this direction and that we should now lie on our oars.

I think, however, it is desirable that we should be represented in this proposed conference, and that if, as many of us think, the specifications which we have already adopted are as good as can be prepared at this time, our committee should work to secure their acceptance by the other societies. If, on the other hand, these other societies can present satisfactory reasons why the specifications which have now been used for some three years should be modified, there is no doubt, I believe, that the Association would be glad to consider the suggested modification, and presumably would accept it on the report of an able committee.

I would therefore make a motion, Mr. President, that Mr. Freeman C. Coffin, Mr. Dexter Brackett, and Mr. F. F. Forbes, who composed the original committee which draughted our specifications now in force, be requested to act as a committee of conference in meeting these other committees and discussing the question of standard specifications for cast-iron pipe. I would say further that I have been able to talk this matter over to some extent with Messrs. Coffin and Brackett, and although they have, perhaps, done as much work in this direction as it is really proper for the Association to call on them to do, I think that they would be willing to give what time may be necessary to a conference of this kind, and would see that the Association's standard is presented to these other committees, and at least consider the subject further and report back to the Association.

The motion was adopted, and the President appointed the committee as suggested by Mr. Sherman.

COURTESIES EXTENDED.

The Secretary read the following letter from the Ryan-Parker Construction Company:

"In connection with the annual convention of the Association to be held at New York City, in case any of the members are interested in the construction of retaining walls and brickwork, we would be pleased to extend to them an invitation to visit the contract we now have under way for the extension of Riverside Drive from One Hundred Thirty-Fifth Street north. The contract for this work, the cost of which is approximately $1 500 000, consists mainly of heavy concrete foundations and retaining walls with facings of finely dressed granite."

On motion of Mr. Sherman it was voted that the Secretary be instructed to write to the Ryan-Parker Construction Company, and to the other companies from whom communications have been received extending courtesies to the members of the Association during the convention, expressing the thanks of the Association.

The report of the Committee on Meter Rates was then taken up. In the absence of Mr. Coffin, chairman of the committee, Mr. Frank E. Merrill presented the report. In view of the fact that advance copies had been circulated it was deemed unnecessary to read the report in full, and gentlemen were invited to proceed to discuss it. The discussion was opened by Mr. Clemens Herschel, who contributed a written paper which was read by Mr. Sherman. The other gentlemen who took part in the discussion were Messrs. Allen Hazen, Edward W. Bemis, Charles W. Sherman, Walter H. Richards, T. H. McKenzie, Hugh McLean, Frank L. Fuller, F. A. W. Davis, W. C. Hawley, Robert J. Thomas, and Frank C. Kimball. On motion of Mr. Sherman it was voted to accept the report and to continue the committee.

The next matter on the program was the report of the Committee on Private Fire Services. In the absence of Mr. F. H. Crandall, chairman of the committee, Mr. Thomas, a member of the committee, suggested that the matter be laid over until the paper on Fire-Service Meters, by Mr. E. V. French, had been presented, inasmuch as he understood that Mr. French's paper would be on the lines which the committee had been endeavoring to work out.

On motion of Mr. Sherman it was voted that the President appoint a nominating committee to bring in a list of nominations for officers for the ensuing year. The President subsequently appointed Messrs. Frank E. Merrill of Somerville, Allen Hazen of New York, Michael F. Collins of Lawrence, Edward L. Peene of Yonkers, N. Y., and F. E. Bisbee of Auburn, Me.

At the afternoon session Mr. E. V. French, C. E., of Boston, presented a paper on "Fire-Service Meters." The discussion which followed, relating also to Mr. Wm. T. Sullivan's paper on "Tests of Large Meters," was participated in by Messrs. Edward W. Bemis, Frank C. Kimball, J. A. Tilden, William F. Sullivan, George A. Stacy, Lewis H. Nash, Robert J. Thomas, F. A. W. Davis, and Morris R. Sherrerd. At the conclusion of the discussion, on motion of Mr. W. C. Hawley, it was voted that the Committee on Private Fire Services consider and report a method or methods by which the value of fire protection can be estimated; and on motion of Mr. George A. Stacy the committee was enlarged by the addition of Mr. George W. Batchelder and Mr. Hugh McLean.

Adjourned.

In the evening the party visited the New York Hippodrome.

THURSDAY, SEPTEMBER 14.

At the opening of Thursday-morning session the Secretary announced that applications for membership had been received from the following-named persons, approved by the Executive Committee:

Richard Veale, Superintendent Water Department, Kearney, N. J.; J. Ralph Van Duyne, Assistant Superintendent Newark Water Department, Newark, N. J.; George E. McLaughlin, M.D., Bacteriologist, Jersey City, N. J.; Myron S. Falk, Consulting Engineer, New York City; Edward Nuebling, Draughtsman, Long Island City, N. Y.; L. M. Anderson, City Engineer, Grand Rapids, Mich.; G. Everett Hill, Civil and Sanitary Engineer, Orange, N. J.; Edward L. Walker, with the Aqueduct Commission, New York City; Samuel F. Thomson, employed on the additional water supply for New York City; Orville J. Whitney, Superintendent Medford Water Works, Medford, Mass.

On motion of Mr. King the Secretary was requested to cast

one ballot in favor of the applicants named, and he having done so they were declared elected members of the Association.

The first matter on the program was the report of the Committee on Uniformity of Hose and Hydrant Threads, presented by Mr. George A. Stacy, of Marlboro, chairman. The subject was discussed by F. M. Griswold and E. V. French. On motion of Mr. Frank C. Kimball it was voted that the report of the committee be accepted and the standard recommended be adopted as the standard of the New England Water Works Association.

On motion of Mr. Frank L. Fuller it was voted that the President appoint a committee of three to consider the subject of uniformity in the direction of opening hydrants and gate-valves, and of size and shape of hydrant and gate nuts. The President subsequently appointed as a committee Frank L. Fuller, Frank C. Kimball, and Edward V. French.

The convention was then addressed by Prof. W. P. Mason, of Troy, who read a paper on the "Relation of Intensity of Typhoid Fever to Character of Water Carriage." Messrs. George A. Soper, F. A. W. Davis, M. N. Baker, George W. Wright, and George C. Whipple took part in the discussion.

The next paper was by Mr. John F. J. Mulhall, of Boston, and was on the subject, "Water Works Accounting." The subject was further discussed by Mr. W. C. Hawley, Mr. A. A. Reimer, and Mr. Edward W. Bemis.

Mr. W. B. Gerrish, of Oberlin, Ohio, then read a paper on "The Water Softening Plant at Oberlin, Ohio." Mr. Frederick S. Hollis, Mr. George C. Whipple, and Mr. Robert S. Weston spoke on the subject.

The President announced that Mr. G. S. Hook had prepared a leaflet on the "Electric Pumping Station of the Schenectady Water Works, Rotterdam, N. Y.," for distribution, and that he would like to say a few words on the subject.

Mr. G. S. Hook. I will not attempt to discuss the general subject of electric pumping, because it is a large matter and deserves more time than can now be given to it. I would simply say that from the point of view of the fire-protection engineer, who is coming to the front so rapidly in these days, and also from the point of view of the water-works man, it seems that the question of

electric pumping will, according to the local conditions encountered, be a question that will be up for solution in many cases where economies will be derived from its use.

The little leaflets which I wish to place in the hands of the Secretary for distribution to any of the members who desire to learn our data on the matter, were gotten out for the information of the New York State Fire Chiefs' Association, at the time they met in Schenectady last May, and it occurred to me that they might be of interest to members of this Association. Later on I expect that the question will become a very large one. The city of Schenectady places its total reliance on its electric company, and was probably the first city in the country to do so. Buffalo has followed suit, I understand, and has had electric pumps in operation about two months. Other places are considering the question, and I have been lately informed that the New York Auxiliary High-Pressure Fire Supply has let a contract for Brooklyn, and contracts are pending for an equipment of emergency pumps in the highlands of Manhattan. Of course this opens up a question which is of rather more interest to the fire protectionists than to water-works men, but these installations show the trend of practice. I have called attention to the matter hoping that it may lead to the presentation of some papers for discussion at future meetings of the Association.

Adjourned.

The afternoon and evening were devoted to a trip by boat around New York Harbor and a visit to Coney Island.

FRIDAY, SEPTEMBER 15, 1905.

Applications for membership were presented from the following:

F. O. Sinclair, engaged in general engineering, Burlington, Vt.; P. A. Maignen, designer of water-purifying plants, Philadelphia, Pa.; Weldon D. Griffin, Arlington, N. J., Assistant Superintendent, New York & New Jersey Water Co.; John E. Hill, Civil Engineer, Newark, N. J.; M. Otagawa, Superintendent and Chief Engineer Water Works, Tokio, Japan; W. R. Scofield, Superintendent Matteawan Water Department, Fishkill Landing, N. Y.

These applications having been duly approved by the Executive Committee, the Secretary was directed to cast one ballot in favor

of the candidates, and he having done so, they were declared elected members of the Association.

The announcement on the program for the morning session was "Symposium on the Relation of Copper Sulphate to Water Supply Matters." It was opened by Dr. George T. Moore, of Washington, with a statement of the general problem, with special reference to the use of copper sulphate as an algicide. Then Prof. W. P. Mason, of Troy, spoke on the use of copper sulphate to guard against typhoid fever epidemics coming from unfiltered surface water supplies. Other papers were read as follows: By Mr. D. D. Jackson, of Brooklyn, on the "Destruction by Copper Sulphate of Typhoid Fever Germs"; by Prof. Henry Kraemer, of Philadelphia (read by Dr. Newcomb), on "Germicidal Properties of Metallic Copper"; by Prof. Herbert E. Smith, of New Haven, on "Toxicological Aspects of the Copper Sulphate Treatment"; by Mr. J. W. Ellms, of Cincinnati (read by Mr. G. C. Whipple), on "The Behavior and Uses of Copper Sulphate in the Purification of Hard and Turbid Waters"; by Mr. George A. Johnson of Columbus, Ohio, on "The Application of Copper Sulphate to the Effluents of Coarse Grained Sewage Filters"; by Mr. H. W. Clark, of Boston, on "Copper Sulphate in Connection with Water Filtration."

There was then a general discussion of the copper question, by Mr. X. H. Goodnough, of Boston; Mr. Karl F. Kellerman, of Washington; Mr. E. B. Phelps, of the Massachusetts Institute of Technology; Mr. Robert S. Weston, of Boston; Dr. George A. Soper, of New York; Mr. Allen Hazen, of New York; Mr. G. A. Johnson, Mr. P. A. Maignen, Mr. G. C. Whipple, and Dr. E. L. Newcomb; and the gentleman who presented papers closed the discussion.

On motion of Mr. Davis the thanks of the Association were extended to those gentlemen, not members, who had presented papers.

At the opening of the evening session the following were elected active members:

Lewis W. Dayton, Oyster Bay, L. I., Superintendent, Green Island Water Supply Co. and General Manager Nassau County Water Co.; W. D. Horne, Yonkers, N. Y., engaged in chemical work; Fred R. Betts, Assistant Engineer in charge of Surveys and Construction, Department of Water Supply, New York City.

On motion of Mr. Sherman, the thanks of the Association were extended to the New York Central & Hudson River Railroad Company and to its chief engineer, Mr. Wm. J. Wilgus, through whose courtesy a special train was tendered for the visit to the Croton dam, the next day; also to the New York Rapid Transit Company mission for facilities afforded for inspecting the subway and power house, and to the Aqueduct Commission of New York. Mr. Sherman added, "If it were proper, I should like also to move a vote of thanks to the committee in New York which has so splendidly arranged for this our most successful as well as our largest convention. Since, however, they are all members of the Association I suppose that it is not proper for me to make that as a motion, but I want it to go on record that we all feel that we are just as much indebted to them as though we could pass them a vote of thanks." [Applause.]

Mr. H. K. Barrows, Civil Engineer, of Boston, delivered an address, illustrated by stereopticon, on "Some Features of Estimating Stream Flow in New England."

Mr. G. C. Whipple, Civil Engineer, of New York, delivered an address, also illustrated by the stereopticon, on "The Water Supplies of the New York Metropolitan District and Vicinity, with Special Reference to their Purification."

Adjourned.

Saturday, September 16, 1905.

A visit was made to the new Croton dam, Plate I, Fig. 1, a special train having been provided by courtesy of the New York Central & Hudson River Railroad Company for the transportation from New York to Croton and return. Refreshments were served on the dam.

A feature noted by many was the reproduction of the badge of the Association around the fountain below the dam, as shown in the accompanying view. (Plate I, Fig. 2.)

Exhibits of Associates.

The following associates made exhibits:

Allis-Chalmers Co.,	Pumps.
Barker Well Co.,	Well-drilling apparatus.

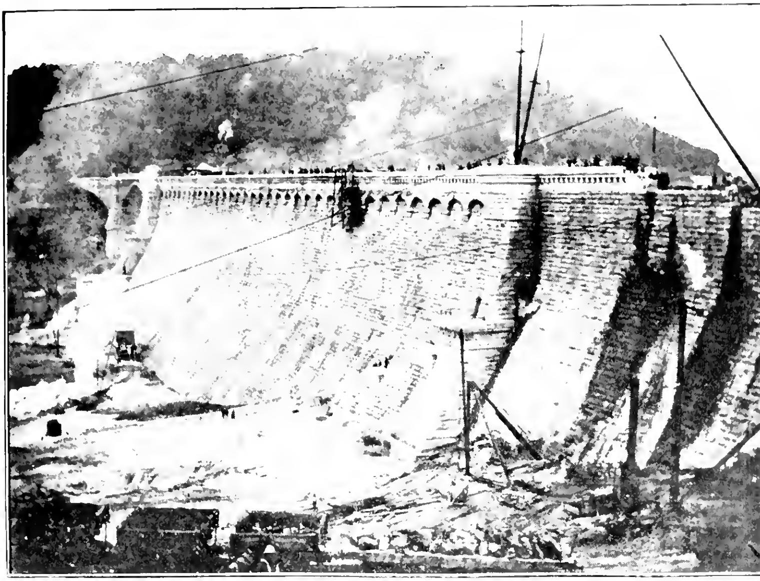

Fig. 1. New Croton Dam, September 16, 1905.

Fig. 2. Fountain below New Croton Dam, September 16, 1905.

Central Foundry Co.,	Universal pipe.
Coffin Valve Co.,	Valves and hydrants.
Fairbanks Co.,	Valves and hydrants.
Fire & Water Engineering Co.,	Publications.
Garlock Packing Co.,	Packings.
Hays Mfg. Co.,	Brass goods.
Hersey Mfg. Co.,	Meters.
Jenkins Brothers,	Pumps, valves, and packing.
Kennedy Valve Co.,	Valves and hydrants.
Lead Lined Iron Pipe Co.,	Lead lined iron pipe.
Macleod, Walter & Co.,	Lights, lead furnaces, and heaters.
H. Mueller Mfg. Co.,	Brass goods.
Municipal News,	Publications.
National Meter Co.,	Meters.
Neptune Meter Co.,	Meters.
Pittsburg Meter Co.,	Meters.
Rensselaer Mfg. Co.,	Valves and hydrants.
Ross Valve Co.,	Valves.
Smith, A. P., Mfg. Co.,	Tapping machines, brass goods, and specialties.
Thomson Meter Co.,	Meters.
Union Water Meter Co.,	Meters.
Water Works Equipment Co.,	Tapping machines and valves.
Worthington, H. R.,	Pumps and meters.
Wood, R. D., & Co.,	Pipe, hydrants, and valves.

FRED. N. WHITCOMB,
Chairman Exhibit Committee.

MEETINGS OF THE EXECUTIVE COMMITTEE.

ATTLEBORO, MASS., June 28, 1905.

Present: President George Bowers and George A. Stacy, James L. Tighe, Frank E. Merrill, Robert J. Thomas, Lewis M. Bancroft, and Willard Kent.

Six applications are received and recommended for membership viz.:

Charles M. Bolton, Olympia, Wash.; Ralph Howard Garrison, Vineland, N. J.; Arthur N. French, Hyde Park, Mass.; Alexander Macphail, Kingston, Ontario; Clyde Potts, New York City; George H. Felix, Reading, Pa.

The President presents form of lease of Headquarters at Tremont Temple, for three years, at four hundred dollars per annum, recommended by sub-committee, whereupon it is voted: that the same be approved and that the President and Secretary are authorized to execute the same on behalf of the Association.

Mr. J. Waldo Smith, of the New York Committee on Annual Convention, very interestingly outlined the plans of the committee in relation thereto, and after discussion the President announced that the date of the convention would be September 13, 14, 15, and 16.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

NEW YORK, September 13–15, 1905.

The Executive Committee met from time to time during the convention and approved applications for membership, but transacted no other business.

WILLARD KENT, *Secretary.*

OBITUARY.

August Fels, member of the Lowell Water Board, died July 3, 1905, as the result of an accident, having been thrown from the carriage while driving.

Mr. Fels was born in Dombirn, Switzerland, February 7, 1844. He came to this country about 1862. In 1864, he became superintendent of a woolen mill at Steventown, N. Y., and about a year later, of a similar mill at Paterson, N. J., where he remained until 1877, when he became agent of the Merrimack Woolen Mills at Lowell.

In 1894 he was elected to the Lowell Water Board, and remained a member until his death. He is survived by a wife and five children.

Mr. Fels was elected a member of the New England Water Works Association on September 13, 1899.

Frank L. Fales, assistant engineer on the extension of the Cincinnati Water Works, died October 5, 1905, in Denver, Colo., where he had gone for his health.

Mr. Fales was born in Milford, Mass., in 1865. He was a graduate of Harvard University in the class of 1888, after which he studied engineering in Switzerland and at the Lawrence Scientific School. He was for several years in the office of the Massachusetts Metropolitan Water Board, but had been since about 1900 with the commissioners of water works, Cincinnati, Ohio.

He was a member of the Boston Society of Civil Engineers, and an associate member of the American Society of Civil Engineers. He was elected to membership in the New England Water Works Association on December 13, 1893.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XIX. December, 1905. No. 4.

REPORT OF COMMITTEE ON UNIFORMITY OF HOSE AND HYDRANT THREADS.

GEORGE A. STACY, MICHAEL F. COLLINS, LEWIS M. BANCROFT, COMMITTEE.

[*Presented September 14, 1905.*]

To the New England Water Works Association: The Committee on Uniformity of Hose and Hydrant Threads, appointed at the annual convention, held at Holyoke, Mass., in September, 1904, beg to make the following report:

Your committee upon taking up this subject realized from the first the many difficulties that surround the satisfactory solution of this problem. For thirty years spasmodic attempts have been made, from time to time, to establish a standard for hose couplings, and up to within a year (there being no coöperation and many of the attempts being without due consideration and study) very little progress was made. Your committee were agreed that there were three things essential for a standard thread:

First, it should be mechanically correct.

Second, it should be one that could be adopted by the principal fire departments, with the least trouble and expense.

Third, it should be such as would receive the endorsement of the fire insurance managers, commissioners and chief engineers of the principal fire departments; water works managers, superintendents, and manufacturers of fire department supplies and equipments.

The various diameters and pitch of threads used by the different fire departments throughout the country are almost equaled by

the variety of opinions as to what is best to adopt, but all are agreed that it is growing more and more important that a standard for hose threads should be established.

To collect and tabulate statistics necessary for the intelligent study of this question, to harmonize the various interests, and to secure their coöperation, required more labor and time than was at the disposal of your committee. We found that there were other committees in about the same position who were, or had been, considering this subject.

The Committee on Standard Thread for Hose Couplings of the National Fire Protection Association, of which Mr. F. M. Griswold is chairman, seems to be the Moses that is leading the various parties considering this question out of the wilderness of doubt and cross purposes to the light of corporation harmony, and a satisfactory solution of this problem.

Your committee desire to express their appreciation of the large amount of work done by Mr. Griswold, ably seconded by his colleagues, in collecting the information and tabulating the statistics from all over the country, whereby an intelligent study of the question could be made.

Your committee received an invitation last April to attend a conference in New York to consider this subject, but the notice was so short that none of the committee were able to attend. Later, by appointment, Mr. Griswold and Mr. Bruen had a conference with your committee at our headquarters, Tremont Temple, Boston, when they presented for our consideration a formula for hose threads and hydrant connections, together with facts and statistics by which they had arrived at their conclusions.

PROPOSED STANDARDS.

The following is the formula adopted by the National Fire Protection Association as a standard:

Inside diameter of hose, in inches	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$4\frac{1}{2}$
Number of threads per inch	$7\frac{1}{2}$	6	6	4
Male couplings: Outside diameter of thread, *finished*, in inches	$3\frac{1}{16}$	$3\frac{5}{8}$	$4\frac{1}{4}$	$5\frac{3}{4}$
Diameter at root of thread, in inches	2.8715	3.3763	4.0013	5.3970
Clearance between male and female threads, in inches	.03	.03	.03	.05
Length of threaded male end, in inches	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{3}{8}$

The above to be of the 60° V-thread pattern with one one-hundredth inch cut off the top of thread and one one-hundredth inch left in the bottom of the valley in $2\frac{1}{2}$-inch, 3-inch, and $3\frac{1}{2}$-inch couplings, and two one-hundredths inch in like manner for the $4\frac{1}{2}$-inch couplings, and with one-fourth inch blank end on male part of coupling in each case; female ends to be cut $\frac{1}{8}$ inch shorter for endwise clearance. They should also be bored out .03 inch larger in the $2\frac{1}{2}$, 3, and $3\frac{1}{2}$-inch sizes, and .05 inch larger in the $4\frac{1}{2}$-inch size, in order to make up easily and without jamming or sticking.

The following arguments were presented for the adoption of the above as a standard:

"*First.* The National Association of Fire Engineers' report for 1891 (Landy) shows a total of 1 339 towns using $2\frac{1}{2}$-inch inside diameter hose couplings having outside diameters ranging, inclusively, from 3 to $3\frac{1}{8}$ inches, and with hose threads covering from 7 and $7\frac{1}{2}$ to 8 per inch; of this number about 70 per cent. can be made to be of reliable service with an outside diameter of $3\frac{1}{16}$ inches by the use of a tap or a die suited to the number of threads.

"*Second.* Messrs. R. D. Wood & Co. (1905) furnish statistics showing that in 811 towns the same conditions exist as to outside diameters and threads, and of these it is demonstrated that 52.6 per cent. could be adapted to the $3\frac{1}{16}$-inch outside diameter coupling by the same means as above.

"*Third.* A summary of 525 cases collated from a most exhaustive itemized list of couplings by Mr. J. R. Freeman, of the Factory Mutual Insurance Companies (1892), shows that 82 per cent. of that number carry the range of 7, $7\frac{1}{2}$, and 8 threads to the inch, with outside diameters to couplings within the above limits, with such variations as promise an equal percentage of adaptability to the $3\frac{1}{16}$-inch outside diameter with $7\frac{1}{2}$ threads to the inch.

"*Fourth.* As above noted, all couplings having an outside diameter included within the range of $3\frac{1}{16}$ to $3\frac{1}{8}$ inches may be cheaply and easily made to conform to the $3\frac{1}{16}$-inch diameter by means of a tap or a die conforming to the size and number of the threads on the coupling.

"*Fifth.* It has been demonstrated that the swivel coupling, cut for $7\frac{1}{2}$ threads to the inch, will make a satisfactory connection to the male ends of couplings cut to 7 and 8 threads where the outside diameter of each is $3\frac{1}{16}$ inches. To accommodate the swivel (female) end of the 7- and 8-thread coupling to that of the $7\frac{1}{2}$-thread, an adapter would have to be used, and this, after

the adoption of a 'standard,' would mean limited expense, warranted by the conditions.

"*Sixth.* While there has always been divergence of opinion as to an accepted standard for hose couplings, the exigencies of the conditions have served to bring together many in authority who are now ready to accept the standard appealing to the best interests of all concerned, and this committee has assurances that whatever is acceptable to it will be accepted by them, and its adoption pushed with energy and persistence."

Your committee, in considering the formula and arguments presented, came to the conclusion that the formula very nearly conforms to the things which your committee consider essential and which were mentioned in the first part of this report, namely: That it is mechanically correct, and that it can be adopted by a large majority of the fire departments of this country with very little trouble or expense. Boston and a large number of fire departments throughout New England use what is called the Roxbury thread, which is $3\frac{5}{64}$-inch outside diameter and 7 threads to the inch; New York City and surroundings use 3-inch diameter and 8 threads to the inch; and so on throughout the country with different threads and diameters, but with the 7 and 8 threads for $2\frac{1}{2}$-inch hose predominating.

The adoption of $7\frac{1}{2}$ threads per inch and $3\frac{1}{16}$-inch outside diameter for $2\frac{1}{2}$-inch hose as a standard is a compromise or middle ground favoring no particular locality, and in the opinion of your committee, from their study of the question and their experience as heads of the fire departments of their respective cities in times past, will receive the endorsement and support of a very large majority of those interested.

In closing, your committee recommend to the New England Water Works Association for their endorsement the "National Fire Protection Association standard for hose threads," the formula of which is incorporated in this report.

DISCUSSION.

MR. STACY. The statement is made in the report that a satisfactory connection can be made by a $7\frac{1}{2}$, with a 7- or 8-thread on an emergency; that is, if a department with $7\frac{1}{2}$ threads was called to assist a city or town that had 7 or 8 threads to the inch, it

could make satisfactory connection. I can show you here an illustration of that fact. [Makes connections.] It is demonstrated that we can get turns enough on that thread to hold any ordinary pressure in coupling up a $7\frac{1}{2}$ to either a 7 or an 8-thread, which is the practical argument in favor of this standard. This is a ground we can all meet on, taking the country as a whole. Of course we New Englanders, if we were just talking for ourselves within our narrow limits, would favor 7 threads to the inch, which the majority of us are now using; but when we take it on the broad ground of a national standard we cannot come to any other conclusion than that the $7\frac{1}{2}$ thread is the proper thing and the wise thing and the least expensive thing which can be adopted by the departments throughout the country.

MR. F. M. GRISWOLD. *Mr. President and Gentlemen:* The matter of standardizing hose thread and hydrant couplings has been one of burning interest for the past thirty-three or thirty-four years, and, as the report of your committee has shown, the efforts to accomplish something have generally stopped with the making of the reports to the various organizations that have undertaken an investigation. The reports have been submitted and printed and that has been the end of them.

When the committee of the National Fire Protection Association was appointed to take up this subject, we felt its importance, and we thought we knew where the other people had failed, and consequently we immediately went to work to bring all you people in who are interested and find out what you knew and what you thought and get all of us working together. And the consequence is, I am very glad to say, that the American Water Works Association in May adopted the schedule which has been suggested by your committee to-day; the National Fire Protection Association adopted it in May; the National Association of Fire Engineers adopted it at Duluth, in August; the National Firemen's Association at Kansas City adopted it the latter part of August, when I was there; and, as your committee has said, 70 per cent. of all the hose couplings in the United States on $2\frac{1}{2}$-inch fire hose can be connected, $3\frac{1}{16}$ outside diameter, $7\frac{1}{2}$ threads to the inch. It has been demonstrated by Mr. Stacy here before you. We have a $7\frac{1}{2}$ female coupling and a 7-thread and an 8-

thread, and they come together and make a mighty smooth joint when you come to handle them. It picks up the 7-thread a little more readily, as you see.

The insurance people have always felt that the interests of what might be called their own selfishness and the broad general interests of the public were alike. We want to see the possibility of Portland, Ore., helping Portland, Me., if it is necessary. It is a pretty long distance between the two places, but in 1873, when Chief Hill at Cleveland, Ohio, made the first proposition for the establishment of a standard he made the statement, "Gentlemen, I want a line of hose which will reach from the Atlantic Ocean to the Pacific Ocean with one standard coupling, and from the Canadian line to the Mexican line in the other direction." Let every man help his brother — and we all owe that duty to our brothers, gentlemen; there is no question about it. We ought not to stand on our own selfishness and on our own private opinion, but we should help our neighbors, and this is one way you can do it. We saw at Baltimore a few years ago the New York department, desiring to do everything it could to aid, come down there and have to tie its hose to the hydrants with wire and wrap the outside with gunny bagging, and they could hardly get water enough to make a stream, so that they were really of no service until they went to Jones Falls where they could get open suction. A little suburb near Baltimore could not be of aid because there was a difference in the hose couplings, and each community was important enough in its own estimation, before the fire came, to think itself "it." The only dividing line between St. Paul and Minneapolis is on the map; you can't find it on the ground. They both have 7 threads to the inch, but each has a different diameter. They are supposed to have adapters which will accommodate the hose of one city to that of the other, but when you come to investigate you find they haven't got them.

Now, after thirty-odd years of delay and hesitation, with graves strewn the whole length of time, the only inscription on the headstones being "inconclusion," isn't it about time that we should conclude something?

Now a word as to what has been accomplished. The city of St. Louis has 6 threads to the inch, and when this proposition

for a standard thread came up they were about placing an order for 40 000 feet of $2\frac{1}{2}$-inch fire hose; and when it was decided by the National Fire Association that a $7\frac{1}{2}$-thread, $3\frac{1}{16}$ outside diameter, was the thing, they said that was what they would have. They will change every coupling in that town where there are a million people and thousands and thousands of couplings to $7\frac{1}{2}$ as against 6. When we went south to attend the meeting of the American Water Works Association last May, we stopped over in Washington. There is a very important bureau there some of us have heard from, the Department of Commerce and Labor, and one of the sections of that department is the Bureau of Standards, and Dr. Stratton is the man who is at the head of it. He had just returned from Paris and had got the metric system pretty well fixed in his head. When we showed this combination to him he threw up both hands and said, "That is an odd thread, $7\frac{1}{2}$ inches." He took out his comparative scale and laid it down and said in surprise, "Why, that will accommodate itself to the metric scale within one two-hundredth of an inch. Now, if you can bring to us the approval of the leading associations of the United States which have the control or management of the water supplies or water use, we will be very glad to present a bill to Congress and have it passed, establishing $7\frac{1}{2}$ threads, $3\frac{1}{16}$ outside, as the government standard." The government cannot compel this city or any city or section of the United States to adopt a standard of any kind, but it can give it the prestige of being the United States standard. And, further than that, if they adopt it as the United States standard it will spread itself throughout the world.

I am not only gratified but I am more than satisfied to feel that so important and intelligent a body as the New England Water Works Association should have received from its committee a report which in my judgment, is irrefutable; you can't get away from it. Now we have everything there is in the country.

Mr. E. V. French. I do not think that I can add anything to the excellent description of all this work which Mr. Griswold has given. I think it goes without saying that a standard is in every way a desirable thing. The evils of the lack of it have shown themselves again and again in conflagrations where one

city could not help another; and it seems to me the work that this association has done along this line, and the work which Mr. Griswold has done, in bringing this matter to a head, not merely stopping with the report, but putting a very large amount of time into the thing, going before these different associations and explaining all these matters, has been exactly the thing which was necessary to bring the desired result about.

I am very glad that the committee of this association has come to the conclusion that this is a proper standard to adopt, and it seems to me that we have now really reached the time when it is sure to become a reality. I think we can all help a little in this way. Recently it came to our attention that one of the large companies was sending out hydrants to fit some of the older standards and were leading in the nipples. We asked them if they wouldn't be willing to screw those in, and then, perhaps, in a year or so, when the towns began to make a change, they could simply enlarge the old nipple or screw in a new one very readily. They replied they would be very glad to do that, but there would be a slightly increased cost. I think if each one of us would go home and urge the hydrant people and hose people to do everything they can to get in line for this change, it will all help to bring it around quicker, and it is certainly one of those things which the sooner it comes the better it will be.

Mr. Frank C. Kimball. In view of this report and the expert opinions we have had on it, I would move that the report be accepted and this standard adopted as the standard of the New England Water Works Association.

Mr. Frank L. Fuller. There is one matter that the committee did not speak of, which I suppose did not come within their province, but which, it seems to me, might well be spoken of at this time, and that is the way in which the hydrants should open. There is a diversity in that respect now, as you all know, some opening to the right and some to the left. It has occurred to me that perhaps the committee in continuing their work might make a recommendation in regard to that, and I should like to have that included in the motion, that they be asked to make a recommendation as to the way hydrants should open, whether to the right or to the left.

Mr. Stacy. I fully coincide with Mr. Fuller's opinion as to the desirability of having hydrants and gates all open in the same direction, but this committee has put considerable work into the subject that they were appointed to consider and have concluded their labors, and it seems to me it would mix things up a little bit now to bring in something that is foreign to the subject which they were appointed to consider. It would be opening up a new field at this time, the importance of which I acknowledge, and I would suggest that the work be carried on by some committee. But we consider that this report closes up and finishes our work, and we wait your approval of the work that we have done, and that will end the matter as far as this committee is concerned. Then if there is any new work to be done, — and there is lots of it of importance, — let us start afresh and have another report, but as chairman of this committee I shall insist that this report be considered as it has been submitted. You can either reject it or adopt it and that will end the matter, and then I would be very glad to see the suggestion of Mr. Fuller carried out, because there is nobody who sees a man on the other side of the street working away with a wrench and hollers, "The other way" to him, but wishes that everybody knew enough to open the hydrant the right way and that they all opened the same way. A man situated as I am, having the charge of the pumping engine as well as of the rest of the works, with the valves in the engine room turning one way and the valves on the street turning another, sometimes in the night, if he is a little sleepy, will have to scratch his head to think where he is. [Laughter.] But that is something which is foreign to the matter before us now, and I therefore shall ask for your verdict on our report as it stands.

Mr. Fuller. I simply mentioned the matter because it seemed to me that the two things were pretty intimately connected, and if the recommendation of the committee could cover both it would be a good idea. However, I don't want to impose any more work on the committee than they are willing to take.

The President. Then you will withdraw your motion?

Mr. Fuller. Yes; I will withdraw my amendment.

[Mr. Kimball's motion that the report of the committee be

accepted and this standard adopted as the standard of the New England Water Works Association was then put and adopted.]

THE PRESIDENT. Does Mr. Fuller want a committee appointed to consider the matter he has suggested?

MR. FULLER. I think this is a matter of a good deal of importance, Mr. President. In my own work I have always been confronted with the question as to which way the hydrants shall open. One man says they should open to the right, another man says they should open to the left, and, as I understand the hydrant men, about half of the hydrants open to the right and about half to the left. Now, it seems to me, it is time that the thing should be settled one way or the other. Personally it would not make any difference to me, as I know of, which way they opened, but, as Mr. Stacy has said, it is an abomination for a fireman to go out and have to be instructed as to which way the hydrants are to be opened, when it ought to be a commonly known thing and there should be uniformity everywhere. And while it seems to me that these two matters ought to go together, for the sake of bringing it before the association I will move that a committee be appointed to investigate this subject and make a recommendation. I understand any expression coming from this association would have a great deal of weight, and I am very sure that the hydrant people would be glad to have something adopted in the way of progress toward uniformity. Therefore, I make the motion that a committee of three be appointed by the President to make some recommendation.

MR. FRENCH. I would like to suggest in addition to that, that the committee also take up the question of the size and shape of nut, and I think it would also be well to include the ordinary gate valves, to see if we can't get the whole thing into one general standard. The National Fire Protection Association, as Mr. Griswold has just reminded me, are taking up both the question of hydrant stem and nut, and I am sure a committee of that association would be very glad to coöperate in work of this kind so far as possible; and I think it could be extended, as I say, to the gate.

MR. FULLER. I intended, Mr. President, to include the matter of the opening of valves, because I think they, of course, should open the same way as the hydrant.

[Mr. Fuller's motion was put and adopted.]

WATER-WORKS ACCOUNTING.*

BY JOHN F. J. MULHALL, PUBLIC ACCOUNTANT, BOSTON, MASS.

[Read September 14, 1905.]

Water-works accounting differs radically from accounting in other lines, excepting only gas, electric light, railway and telephone companies, due principally to the number and variety of the auxiliary books necessary for completeness of records as to revenues, operation, maintenance, and construction.

In order to treat this subject intelligently, it was deemed best to commence this paper on the assumption that a complete water works of modern type had been constructed, and was in readiness for operation, even though part of the paper might be considered as rudimentary in a gathering of water-works officials.

On the commencement of business, the public or quasi-public water-works corporation generally issues a pamphlet or flyer, embodying its rates, rules, and regulations, a copy of which is at the disposal of all citizens, and at the same time opens what is termed an —

I. APPLICATION BOOK.

Boston, Mass. . . . . 1905.

Consumers' Water Company.

The undersigned hereby makes application to the aforesaid company for a supply of water at (his or her) premises, located at . . . . and occupied by . . . . for . . . . purposes only, and agrees to pay for same in accordance with the rates, rules, and regulations of said company, now or hereafter in force; and further agrees that the said company may enter upon the premises or any lands owned by . . . . or in which . . . . . . has a right, for laying all pipes that may be necessary for water-supply purposes, and that said company may inspect and repair such pipes at any time when occasion requires.

(Signature) . . . .

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* Extract from a forthcoming book entitled, "Quasi-Public Corporation Accounting and Management," copyright, 1904–1905, by John F. J. Mulhall.

This is the authority or contract under which the water-works superintendent makes the service connection.

II. SERVICE CARD.

When the connection is completed, the service-pipe inspector makes out what is termed a service card, showing the size of the connection, kind and length of pipe from main to property line, with gates, etc., thereon; and on the back of the card showing a sketch or diagram of the connection. If desired, these data can be plotted on the large set of plans showing the system of works and connections therewith. If company charges consumer for tapping distribution pipe, or for the pipe from same to his property line, bill can be made directly from this card and proper record thereof made in the registers hereinafter described, after which the card can be filed.

III. PLUMBER'S CARD.

After the plumber has installed the fixtures in the house, he makes his return on what is termed a "Plumber's Card," showing for what purposes supply is used, and the number and kind of fixtures connected; also any fixtures or connections which may be used on the outside of the premises, and submits same to the company, whose representative makes an inspection of same and, if found satisfactory, countersigns the card. The details of the fixtures connected with the service can then be transferred to the inspection part of the register and card filed.

IV. WATER, TAP, AND SERVICE-PIPE BILLS.

All bills for water, taps, and service pipes are first entered in their respective registers. In order to avoid confusion and to expedite posting, bills for metered water, unmetered water or fixture rates, service pipes and taps, should be printed on paper of different colors. Bills are made with stub attachments, the stubs being retained by the collector as his voucher for moneys received.

The collector then submits his report to the treasurer or other officer, on a printed form arranged in a columnar manner, showing the number of service, name of consumer, amounts paid for water (meter and fixture basis separately), taps, service pipes, miscel-

laneous, and date when paid. The total of this report should agree with the total of the amounts as indicated on the stubs which he detached from the bills. When transmitting cash or check to the treasurer for the amount of the report with stubs attached, he receives from the treasurer voucher signed by him, which is made detachable from report by a perforated line.

Should the collections be made directly by the treasurer, he could make out a "statement of collections" on a form similar to the one described, and attach the stubs thereto, posting payments to the respective customers' accounts in the registers. The totals of the columns on these statements, viz., "Metered Water," "Fixture Rates," "Service Pipes," "Taps," etc., should also be posted to his cash account, under their respective columns, either daily, weekly or monthly, as the occasion demands, after which the statements can be filed. In a large works these statements should be written up and posted daily.

Another method is by th euse of a controlling account: At the end of certain predetermined periods to debit customers' accounts in the main ledger with the total amounts as shown by the respective registers for water, taps, service pipes, etc., and crediting these accounts in said ledger, also crediting customers' accounts and debiting cash when payments are made, and to make proper entries or allowances for all abatements, rebates, outstanding accounts, etc., at the end of the fixed periods.

V. COMBINED INSPECTION AND WATER REGISTERS.

The combined inspection and water registers, both for metered and unmetered water, are, outside the cash book, journal, and ledger, the two most important books of original entry in waterworks accounting.

The inspection part of the book will show all the details of each service, such as, service number, consumer, fixtures in use, meter number, size, kind, location, purposes used, etc., which have been transferred from the plumbers' cards. This part need be entered only once during the life of the book, which can be made to run for any number of years, preferably *five* years, on account of soiling from frequent handling. If there is a change in the fix-

tures or consumer, such change can be entered from the "House-to-house inspection" or the "On-and-off" book.

The financial part of the book is arranged in a columnar manner, having columns for amount due for water, service pipes, taps, miscellaneous, rebates, discounts or abatements, amount paid, when paid, and balance due for the unmetered register; for the metered register, reading cubic feet, difference, rate, amount due, discounts or abatements, amount paid, when paid, balance due.

By this method you will have at all times a complete record of each service connected with the mains, and its status, obviating the necessity of referring to other books when any question arises.

All bills should be entered according to the character of the service, either in the "metered" or "unmetered" registers.

When payments are made, the respective customers' accounts are credited in these books, and the totals are debited to cash under the respective accounts in the main ledger. At the end of any period, the total amount of payments should agree with the amounts received by the treasurer. These books are self-balancing, — the total amount of all bills rendered should equal the totals of the columns, rebates, discounts or abatements, amount paid, and balance due.

If the accounts are kept by the controlling method, the collections should be credited to their proper accounts in the main ledger.

For a large city, it would be advisable to divide the city into sections or wards, allotting books to such sections or wards in accordance with the policy adopted by the city, viz., whether payment for water is made on a metered, or fixture, room, valuation, frontage, or other basis, or combination of same, thus proportioning the books and work of accounting to different bookkeepers.

If desired, the columns for service pipes and taps could be eliminated from the above-mentioned books, and a separate book kept for these accounts, as charges seldom occur after the first installation, — then only for repairs or renewals.

VI. HOUSE-TO-HOUSE INSPECTION AND METER BOOKS.

These books are of such a common character that it is deemed unnecessary to make suggestions therefor. They can be printed and bound in a small book easily carried by the inspector, or else on loose leaves or cards and transcripts made directly to their respective registers; no entry or transcript is required to be made in the inspection part of the registers unless there is a change in the fixtures or name of customer. They should be arranged by streets or routes.

VII. ON-AND-OFF BOOK.

This can also be arranged in a columnar manner and kept on block form of loose leaves or sheets, manifolded, the manifold copy being sent daily to the bookkeepers to make proper entry in their registers of the services "on" or "off." If kept in a bound book, abstracts of daily changes should be sent to the bookkeepers.

VIII. CASH BOOK, JOURNAL, AND LEDGER.

These three books can be combined in one book for a small works, allotting the first part to Cash, the second to Journal, and the last part to Ledger, in the proportion of one half, one eighth and three eighths, respectively.

The journal and ledger are of the usual ruled form, but the cash book is arranged in a columnar manner, both on debit and credit sides, thereby making it a "Cash Ledger."

The following suggested headings or columns for a cash book are intended for a well-equipped works in a large city, — which can be added to or reduced to meet the needs of any works.

For Debit Side:

Water.							Meter Rentals.	Service Pipes.	Taps.	Expense.	Other Ledger Accounts.
Metered.	Fixtures.	Public Hydrants.	Private Hydrants.	Flushing.		Miscellaneous.					
				Streets.	Sewers.						

For Credit Side:

Expense.					Repairs and Renewals.							Salaries and Wages.				Fuel.	Taxes.	Interest and Discount.
Oil.	Waste.	Rent.	Insurance.	Miscellaneous.	At Pump. Station.	Mains.	Service Pipes.	Meters.	Reservoirs.	Filters.	Misc	At Pump. Station.	At Filter.	At Office.	General.			

Construction.					Other Ledger Accounts.
Extension of Mains.	Service Pipes.	Meters.	Tools.	Miscellaneous.	

The totals of the respective columns, excepting only "Other Ledger Accounts" column, can be summarized at any given period, and posted by one entry direct to the ledger, thereby avoiding a great deal of unnecessary bookkeeping.

The column "Other Ledger Accounts" is intended for any personal or impersonal accounts with which it is desired to open an account in the ledger, and requires separate posting for each account entered in this column.

If payments are made by check, with voucher attached, columns can be inserted for "Voucher No." and "Total of Vouchers," if desired.

Another method is to open what is either termed a Distribution Book, Accounts Payable, or Vouchers Payable Book, in lieu of making distribution of accounts in the cash book, and make the distribution under the suggested headings for all disbursements; also open an Accounts Receivable Book, distributing the receipts under the suggested headings; and open controlling accounts with said books in the main ledger. This method is in use, as a rule, only in the largest quasi-public corporations.

IX. AUXILIARY BOOKS.

These books have only an indirect bearing on the revenues, operation, maintenance, or assets and liabilities of a plant; nevertheless they are important as a means of ready reference, and should be kept by all works.

(A) *Construction Record Book.*

This book, as its name implies, shows size, kind, lengths, and location of all pipes, hydrants, valves, valve boxes, meters, etc., which are buried in the ground to a great extent; and details and sketches of other structures, such as pumping stations, reservoirs, standpipes, filters, etc., culled from the original specifications or contracts for building the same. It contains all information which a general plan of the works should furnish, but in addition gives the details on all parts of the construction. It is assumed, however, that all works would at least have a general plan showing the pipe system and connections.

Information of this character should be a matter of record, for in case of absence, disability, or the sudden death of a manager or superintendent of a plant, who alone was the possessor of these data, emergencies might arise, such as a break in the mains, which might cause loss by flood alone running into the thousands of dollars. As a means of ready reference, alone, it will economize in time and labor, and at times avoid large financial outlay to properly locate the pipes and other structures which have been buried in the ground for years.

For a large city it would be advisable to have a construction record book covering the whole city; and in addition thereto, sectional or divisional construction record books, each superintendent of a division or section being furnished with a copy of the construction records pertaining to his division.

(*B*) *Gate Book.*

This book is in the nature of a small sketch book, which can be carried in the pocket, showing the location of gates and hydrants by streets, and is invaluable to a superintendent, as it obviates the necessity of consulting the plans continuously. If more than one copy of the book is desired, the original sketches can be made on tracing cloth, and blueprints made therefrom at a small expense for any number of books. They should be indexed by streets. For large works, gate books should be allotted to each division or section.

(*C*) *Pumping Station Record Book.*

This is kept by the engineer or his assistant, and shows the time of pumping, number of revolutions of the pump, kind of coal and amount used, number of gallons of water pumped daily, etc.

Computations from these data can be made which will show the amount of water pumped during the year, either by water or steam power, and whether the pump is performing duty equivalent to its rated efficiency. If not, there is a loss in delivery, which is commonly called "slip," and it would be advisable to have the pump tested and put in repair, thereby keeping down operation charges in reducing the amount of coal consumed.

wear and tear on pumping machinery, and additional cost of extra engineering force.

(D) *Filter Record Book.*

This book is kept by the operator at the filter plant, in a columnar manner, with columns for day of month, duration of pumping, head on filters, before and after using, number of filters in use, water filtered in twenty-four hours, average rate of filtration per filter, amount of water used in washing filters, amount of alum used, other chemicals, compartments cleaned, turbidity, temperatures (air and water), results of analyses, and column for remarks, under which can be entered such data as when filters were replenished and washed, number of men employed, teams, etc.

(E) *Meter Test and Meter Repair Books.*

These books are more in the nature of records of the comparative efficiency and durability of the different kinds of meters on the market, and can be arranged in a columnar manner, showing the kind and size of meter, maker, head, openings or size of streams measured, discharge (cubic feet), percentage of loss on rated efficiency, etc., with column of remarks, under which can be entered the conditions under which the test is made for the meter test book.

For meter repair book, columns for date set, maker, kind and size of meter, date repaired, with extended column for repairs and renewals, sub-divided into columns for spindles, disks, casings, frost cases, bolts, etc., following with columns of cost and remarks.

These books can be made up in bound form, loose leaves, or the data kept on cards, as seems most desirable.

In conclusion, I would state that the greater part of these books, excepting only a few thereof, have been in use for the past twenty years by Messrs. Wheeler and Parks, — latterly Mr. William Wheeler, who purchased Mr. Parks' interest, — large owners and operators of water works throughout the United States, with whom I have been engaged during that period.

DISCUSSION.

MR. W. C. HAWLEY.* The paper presented by Mr. Mulhall certainly outlines an admirable way of keeping the accounts of a water department or water company, but there are one or two things which might be of considerable value in addition. I find that when we have an argument with some of our consumers, sometimes there is a great reluctance on their part to accept a record which one of the employees of the water company has made, as to turning off the water, turning it on, repairs, etc. Doubtless some of you other gentlemen have come across that same condition. If you have to go into court with your books, you will find even a greater reluctance on the part of attorneys and juries to accept such evidence.

For that reason our company has prepared a set of books, in the form of orders, — one book for turning on, one book for turning off, another book for meter repairs, service repairs, and so on, covering all those things for which we may have to charge and of which we want a record. The consumer's signature is required on those orders. The various original orders are printed on different colored papers, and the orders are in triplicate, the second and third being carbon copies. One carbon copy remains in the book as a record, the second carbon copy goes to the foreman of the proper department, and the original remains in the book until the foreman has made his return and has entered up his record on it and then it is filed with the original contract in the contract file. At any time when we wish to know the history of the contract we can turn at once to it and there are the original papers with the signatures of the consumers, which we find very much better evidence than simply a record in our ledger, for instance, made by a clerk.

I had an illustration of that recently when a lady with one of those automatic ball-bearing tongues came in and spent nearly an hour telling me her troubles. I was at a loss how to settle the matter with her, until one of our clerks who overheard the argument happened to go to our contract file — it isn't all completed, we only have part of it ready — and fortunately found that this

* General superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

particular contract had complete records with it, and I was able to show the lady that on the day she said she had ordered the water off she had really signed a contract and an order to turn it on. On the day she ordered it turned on, according to her story, she signed another order to have it turned off. It didn't take long to settle the matter then. Such a record is of very great value.

Mr. Mulhall. I will say that this paper of mine is intended as a rough draft, a sort of groundwork, as it were, for water-works accounts. It would not cover the case of some city where the ordinances, or their desires, might require the on-and-off book or other books to be kept separately. This is condensing matters into the smallest number of books, which I find to be the desire of water-works people as a rule. A book could easily be made for the "on" services and another for the "off," or a book could be arranged, the first part of it for the "on" and the latter part of it for the "off," and as the customers have to sign the book they would have to come to the main office.

I will say further that the cash accounts which are recommended would not apply to small works, because they would involve too much bookkeeping. They would have to use their own judgment as to what accounts they wanted to open so as to reduce the work to a minimum.

Mr. A. A. Reimer. I should like to ask Mr. Mulhall what he has found the opinion to be regarding the keeping of records by the card system rather than by the loose ledger or open ledger plan?

Mr. Mulhall. Well, being an accountant, I must say that I should be entirely opposed to the card system for financial records; I would not for a moment recommend cards for people to keep their financial data on, — my reputation would be at stake.

In the first place, supposing you do use cards, you have got to buy office furniture which takes up considerable floor space for a large concern, floor space for which rent ranges from $1.50 to $3.00 per square foot in the large cities, and if capitalized at 4 per cent. would amount to a great deal of money, which is equivalent to an original investment of that amount. You really have to buy

special furniture; cards are common and you can buy those anywhere. So much as to the first cost.

Now, coming down to cards as a matter of keeping records,—it means you have to find the proper card in the bunch, take it out, put it on the table, fill your pen with ink and write on it, then blot it, put your pen down and put your card back in the place from which you took it. All that takes a great deal of time, and if time is worth anything you shouldn't use it in that way. I know the card system was installed in some places and taken out again. The Chicago Gas Company put in the card system and got tired of it; the Lawrence Gas Company and the Somerville and the Malden Electric Light Company, I understand, and the Walworth Manufacturing Company, and Lowell Machine Shops. I would add here that the Walworth Manufacturing Company did not install it with reference to their financial affairs but only to keep tabs on different pieces of fittings and things of that nature.

I think cards are excellent for records of service pipes, plumbers' work and possibly meter records, and things of that sort, where there are no financial data connected with them. Cards can be lost and the loss of one may throw your whole accounting system out of gear. Then consider the question of the possibility of theft, and getting rid of cards to destroy evidence. The card system is accepted in court as a matter of record when there is nothing else available, but it hasn't the standing a bound book has, and in fact it hasn't the standing of a loose leaf. There is a great force back of the card system, I mean a financial force, but very few accountants recommend it. I have never known one who did. In fact, I have only known one accountant to recommend the loose-leaf system, but the loose-leaf accounting has many valuable points in its favor. It is not so easy to lose a leaf as it is to lose a card; and audits and totals can be secured a great deal quicker. All the advertised advantages, however, of both the loose-leaf and card system can be incorporated in bound books. Cards are entirely out of the question with me, anyway.

Mr. Reimer. I thank the gentleman for the information, but I may say that in the department with which I am connected we have had a great deal of success with the card system in both

the financial and the operating departments. I know that the clerks in my department would not have anything else if they could have their choice. As regards the opinion of experts, the department has been recently audited, and in their report the experts most heartily favor the card system and advocate it very strongly for the water department, — that one department of the city only, but very strongly for that department. I wanted to state what our experience had been in case others were contemplating the use of the card system.

MR. KENNETH ALLEN.* I may say that the city of Baltimore uses the card system entirely in its water accounting, and I understand it has been found to work very satisfactorily there. We use it in Atlantic City only for the record of services, and have just introduced it for keeping a sort of stock account, so that we can destroy the cards when they are used up. That is, when we have filled the card we transfer to another card and throw the old one away. For the keeping of ledger accounts I think there are some strong arguments in favor of the old book systems.

MR. EDWARD W. BEMIS.† The card system as a method of keeping the accounts of the meter departments of a water works has been challenged. I rise not exactly to pick up the gauntlet, because I do not claim to be an expert accountant, but I will state that the Cleveland Meter Department is entirely on the card system, with the exception of certain books of the double entry system, which fits into the card system, and which was adopted and worked out for me by a member of the Ohio Accountants Association, Mr. Carl Nau, now of Cleveland, who is recognized as one of the best accountants in Ohio. He states that the system which he has worked out to supplement the card system has made it absolutely safe. Other investigators, such as the state of Ohio supervisor of municipal accountants, who is a part of the state auditor's department, — Ohio is the only state in the Union except North Dakota which has a supervision of all the municipal accountants, — he has looked into the matter to some extent and considers that we have an entirely safe system. The details of it I will not go into. I think I will ask Mr. Carl Nau to

* Superintendent of Water Works, Atlantic City, N. J.
† Superintendent of Water Works, Cleveland, Ohio.

prepare a statement and I may send it on to be read at some future meeting, if he cannot attend. It will explain why it is considered a safe system.

In the matter of economy of time, I may say we have saved a great deal. You see we are metering so rapidly that it is a great convenience at every six months term to put in the new cards by streets and by the particular location on the streets. We had 30 000 meter cards the first of April, and we will add 10 000 more the first of October, owing to the results of our meter setting the last six months, and we want to put them in the order of location. We have several checks on this. For example, we have a book record of every connection in the city, and we audit the card system every little while by this record of the number of connections. Then we have the meter reading books as another system of auditing. Then we have the stubs of all the meter bills in the auditor's office, which is another system of auditing. And we have set up a system of double-entry bookkeeping, with a competent bookkeeper in charge, in connection with this card system, each street, I believe, being reckoned as a separate account and all the cards on that street being charged up in the account and then audited. The whole system has to be audited by streets every term. I am not sufficiently familiar with all the details of the system to be able to defend it against such an expert accountant as has attacked it this morning, but I thought I would merely say that I do not think we are yet the awful warning which it has been said that those cities which adopted it would be, and I especially wanted to say that the system does have the approval of very eminent authority, and was, in fact, worked out by one of the best expert accountants in the West.

Mr. Mulhall. Mr. President, I acknowledge that the card system for certain purposes is very good, such as keeping meter records and service-pipe records, or anything which does not bear upon the financial data; but as a rule, and I think the best practice and experience bear me out, in very few cases is the card system used for financial records. Very few quasi-public corporations are on the card system. They are generally either on the bound book or the loose leaf. The New York Gas Company and Electric Light Company would no more think of using the card

system than — well, than I would. The Providence Gas Company would not tolerate it. The Portland Gas Company had cards in and took them out; the Chicago Gas Company did the same thing.

Now, I haven't looked up the reasons why they took them out, because I am satisfied in my own mind that it takes about twelve to twenty times as much work for a bookkeeper to handle the card system as it does the bound book or the loose-leaf system, for the simple reason that you have to take a card out every time you make a record, and put it on the table, blot it and put it back. That is for just one record, there being only one account to each card.

Now to get up monthly statements, by the bound book or loose-leaf system you can add up the accounts of from 20 to 50 customers at once to get the monthly total; if you have the card system, where there is a large number of customers, you would have to take out each card and either call it off to a machine operator or jot the amount down on a piece of paper, which increases the liability of error proportionately to the number of times handled. To get the accounts to balance they sometimes have to go over it two or three times. Card accounts, furthermore, are not self-balancing.

I know of a case at the present time, I am not at liberty to state where it is, where they have adopted the card system, and they have about 120 000 customers, and they are at sixes and sevens now. The parties who introduced the system had their representative there looking out for it for about a month. The cry in the office is, "Put the card back in its proper place always." "Don't touch that box." "Don't take that card out." There are 120 000 customers and about 100 or possibly 150 clerks, and think of the possibilities of cards being taken out and mislaid or lost, especially when they are handled by so many clerks.

It takes a larger force to handle the card system, and the expenses of the extra force of employees necessary, together with the cost of adding machines and renewals thereof, should be capitalized in arriving at the first cost, in addition to the floor space previously mentioned.

I was talking the matter over with the treasurer of a large gas and electric light company, who were on the card system, one

day, and he said, "Well, there are a great many things against the card system; what you told us is true." They all acknowledge that they lose or mislay cards at times, and the loss of a card is an occasion of sorrow to the treasurer or to the financial man in charge of the department.

But supposing they don't lose cards. It takes them, as I said before, a greater length of time to add up the total customers' bills for a month or day by the number of times they have to handle the cards and put them back. They are not self-auditing.

I have got some objections here, while I think of it. The treasurer of a large gas company suggests these objections:

1. Only one account to a card.

2. Harder and longer operation to post. Work in ratio of 20 to 1. (He says 20 to 1; I said 12 to 1.)

3. Not self-auditing.

4. Not approved by auditors.

5. Longer time to get totals.

6. Danger of misplacing or losing cards.

7. Can't put in ordinary vault.

8. Numerous and expensive filing cases for present and future use.

9. First cost of fixtures, of files, etc., excessive.

Now, I didn't think this subject was coming up here, but I happened to have these data on hand in my memorandum book.

Another case I know of where a party is enthusiastic over the card system. He has put in one vault which cost him about $500 and he is going to put in another vault to cost $500 more, to take care of a few more cards. Books could go into the vault all right, books can be arranged for a vault. You are not liable to lose a whole book at once; you are liable to lose a card. I will acknowledge what the gentleman said. He will find some people who will recommend it to a certain extent, but not for financial data.

Mr. Bemis. Mr. President, I am delighted to have these things brought out, for nothing can do us more good than to have all our positions challenged, and it will furnish the basis, I hope, for a further discussion at some future meeting. I will merely say that in the year or two this system has been on trial with us

not a card has been lost. There are only a dozen clerks who have access to these 40 000 cards. And as to the matter of time, I am sure we manage it so that we gain time rather than lose it. Addition may not be quite as quick although with the adding machines it is very rapid. But where we may lose a little in that we gain in the ability to refer readily. Every day in the collection department there are large numbers of people who want further information about their bills, — we sometimes have complaints about them, — and we can instantly produce the card which has on it the last meter reading, the present meter reading, the amount of water used between, and the bill made out on that basis. That is all on one card. And we have on the same card the previous bills running back from one term to seven or eight. And if we want to go back further, if the card in use does not go back far enough, we can go to another section where we have the previous card. I think the gain in ready reference in answering questions and complaints of consumers is enormous, and in the opinion of our clerks who have worked under both systems it more than counterbalances the slight loss there may be in addition. And, further, I will say that our accounts balance to a penny every six months thus far; how it will be hereafter remains to be seen. I merely want to state that there is more possibility of using the card system satisfactorily than perhaps might have been inferred, although it must be supplemented by a controlling account set up on the general ledger of the department and be a part of the comprehensive double-entry bookkeeping system.

RELATION OF INTENSITY OF TYPHOID FEVER TO CHARACTER OF WATER CARRIAGE.

BY PROF. W. P. MASON, TROY, N. Y.

[*Read September 14, 1905.*]

Typhoid epidemics following the use of polluted river water are commonly mild in character, while isolated country cases of the disease are often severe. Such has been the writer's experience, and a reasonable explanation would seem to be that while the adverse conditions of river carriage supply abundant opportunity for the pathogenic germs to either die, or to at least lose a portion of their virulence, the conditions governing the use of water from an infected well usually admit of a shorter period of time elapsing between the entrance of polluted material and the drinking of the water. In other words, the struggle for existence during stream transmission will cause a decrease in the "poisoning power" of the typhoid germ, which decrease will vary directly with lapse of time, and will consequently be a function of both distance and velocity of flow. Bacilli, therefore, which started on their journey in vigorous health might be considered as arriving at the point of invasion in a state so enfeebled as to be incapable of producing a "normal" type of disease.

Such a proposition was advanced by the writer some two years ago in an important case involving the question of water-borne typhoid, and the following data are offered in support of the argument.

At Waterville, Me., there recently arose an opportunity to study an outbreak of typhoid fever occurring among people who used waters of widely different characters. The public supply of the city was from a stream which received the sewage of a town a few miles away, and many cases of typhoid occurred among those who exclusively used such water. Throughout the town there were numerous grossly polluted domestic wells, and fever cases were plentiful among families using water from no other

source. As was to have been expected, a still larger number of cases of the disease were found where the water drunk was from both the wells and the river. A careful house-to-house visitation elicited the following data. The division of the cases into "light" and "severe" rests upon the statements of the attending physicians.

Water Used.	Number of Cases.	Light Cases.	Severe Cases.	Ratio of Severe Cases to Total Cases.
Stream	61	44	17	27.80%
Well	46	20	26	56.50%
Mixed	132	72	60	45.45%

Data such as the above are very difficult to secure, and we are usually forced to rest satisfied with mortality returns alone, but even from such unsatisfactory material our proposition receives no small measure of support.

In a report prepared for the Parliamentary Bills Committee of the British Medical Association, Hart gives sundry figures for a number of British epidemics of typhoid fever. It is possible to pick out from his collection of facts 108 instances where the disease could be traced to contaminated wells upon the one hand, or to polluted reservoirs or streams upon the other. The table here following gives the average death-rates for the two classes of epidemics, and there are added the figures for milk epidemics also, although such are foreign to the present discussion.

	Average Death-rate.
75 epidemics due to well waters	11.83%
33 " " " stream and reservoir waters . .	9.85%
20 " " " milk	12.79%

In speaking with the writer upon this general subject, a Philadelphia physician of large practice said that his typhoid death-rate in private practice was about 5 per cent., but that upon one occasion it was much higher. He was called to attend an outbreak of the fever occurring among a considerable number of Russian sailors, who had been sent to Philadelphia to man a battleship then building at Cramp's shipyard. These men drank water from a well which was afterwards proven to have been grossly polluted. The typhoid death-rate resulting among them was about 20 per cent.

Such figures as have been given certainly tend to show that greater or less concentration of polluting material and longer or shorter exposure of the typhoid germ to unfavorable surroundings must be held to account in part at least for the variability observed in the intensity of the disease.

One word further, if I may be pardoned for taking your time. I have seen quite a number of figures of recent date with reference to typhoid fever, notably those from the city of Columbus. Both the number of deaths and the number of cases were reported monthly. It was peculiar to observe that when typhoid was not very prevalent in the city the death-rate was very high — most of the patients died; but when typhoid fever was really widespread and there was an epidemic, most of those attacked got well. That merely shows, of course, that when there is but little doing in the matter of typhoid the cases are not reported. Physicians will report cases during an epidemic, but they will not report them during a non-epidemic period unless they should happen to be fatal.

DISCUSSION.

Dr. George A. Soper.* Dr. Mason has brought together a number of convincing statistical facts which confirm a view which, as he says, is not entirely new, having been pronounced by him some years ago, and which has been, I fancy, very generally accepted. Much credit is due him for gathering these statistics which he has cited. Statistics of typhoid are exceedingly difficult to collect. Even under the best circumstances, it is almost impossible to tell how many cases of typhoid occur in any epidemic; and during the times when there is no epidemic, it is practically impossible to know even approximately how much typhoid is at hand.

Dr. Mason has struck a note in his concluding remarks which, I think, we should all take particular notice of, and that is that physicians are so often delinquent in reporting their cases. I think we all ought to insist, when cases of typhoid fever come under our notice, that they be reported. In no other way can the prevalence of typhoid fever throughout this country be brought finally under control.

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*Sanitary Engineer, New York City.

I have a few facts which confirm Dr. Mason's argument that typhoid fever which has been produced by drinking infected well water may be more severe and more fatal than typhoid fever brought by water from a distance. In a paper which I read at the last convention of this Association upon the epidemic at Ithaca in 1903,* I mentioned that the epidemic was exceedingly widespread through the city and that the death-rate was about 7 per cent. Towards the end of that epidemic, — in fact after it had ceased, — there was a sudden outbreak which was traced to a well. In that instance every case of typhoid fever was extremely severe and the death-rate was 10 per cent.; fifty people were attacked and five died. The person who infected the well had a very mild case which was contracted from the water supply.

There are probably excellent reasons why the disease is more intense when the germs have only recently passed from the sick. Laboratory experiments and field experience indicate that the germs become attenuated by remaining a long while outside of the body under unfavorable conditions, and so lose their power of producing the typical form of typhoid fever which can easily be recognized by the physician. At the same time, it must not be forgotten that all of the diarrheal diseases which occur in an epidemic are not, in all probability, due to typhoid germs. The same conditions which lead to the infection of a water supply by typhoid bacilli are likely to lead also, and at the same time, to its infection by germs of other enteric disease. In any large epidemic, therefore, it is not improbable that we have to deal not only with typhoid but other enteric diseases which pass for typhoid. This may account in part for the comparatively low mortality in some typhoid fever epidemics, traceable to public water supplies. When a well becomes infected with typhoid bacilli, it is not so likely that the germs of other enteric disease are present also.

It is a matter of doubt, in my mind, whether the length of time which the bacilli have spent in passing from the sick to the well is the main element in reducing their vitality. The time at Ithaca and Watertown seems to have been as short as in some well epidemics. At Ithaca the infectious matter which produced the epidemic could not have traveled more than twenty miles.

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* JOURNAL, December, 1904, vol. 18, p. 431.

and it passed over this distance at a time when the stream was in freshet. It was probably a question only of a few hours from the time when the infectious material was let loose to the time it reached the intake of the water works. At Watertown the nearest village was 4½ miles away, and the farthest from which the infectious material was believed to have come 17 miles, and the water supply in this case also became infected during a freshet. It is probable, therefore, that in these two extensive epidemics the infectious material was only a few hours in passing from the place where it originally lodged to the water works. It is true, however, that we do not know how long a time was actually consumed by the bacilli in their passage from the sick to the well in these instances.

With respect to the difference between the mortality among the Russian sailors and among the private patients of the physician in Philadelphia, I think the care that the different people received may account for a good deal of the astonishing difference in the death-rate. Care in typhoid fever is the best cure we know. Among people who can afford the very best nursing, the death-rate is lower than among others. Among sailors the death-rate from typhoid seems always to be exceptionally high.

MR. F. A. W. DAVIS.* Mr. President, while I of course believe everything that the experts say, I should like very much if they would turn their attention to fixing definitely, if they can, if there are not other means of spreading typhoid fever than through water, although I suppose we must confess that water is the largest carrier of typhoid fever. We are very much interested in this question in Indianapolis, and we have spent considerable money and time in the investigation of it; and we are satisfied that we are still a long way from ascertaining the exact causes of the spread of typhoid fever.

DR. MASON. Of course, as we all know, a very considerable amount of typhoid fever is capable of being transmitted by flies. A ponderous tome has recently been issued, published by the Government, the main subject of which is typhoid fever during the Spanish-American War. The surgeon of one of the New York regiments has told me a pretty grewsome tale about the

* President Indianapolis Water Company, Indianapolis, Ind.

spread of typhoid fever by flies, and he is a man who knows what he is talking about.

With respect to other modes of transferring typhoid fever from person to person, there is the mode of secondary infection which is referred to so often by Sedgwick in his reports, where filthy surroundings allow filthy people to have their filthy hands come directly in contact with food. So far as milk epidemics are concerned, of course they are water epidemics after all, because they result from the filling of milk into cans which have been washed in polluted water.

One word more, if I may be permitted. I do not wish to lose sight of the main distinction between 20 per cent. and 5 per cent. in the death-rates to which I have referred in Philadelphia. Dr. Soper in his remarks has said that a great deal depends on the nursing. That is true, but you must remember that these two death-rates were in one man's practice. That is an important fact to be borne in mind. And while those Russian sailors were doubtless not the richest people on earth, they probably had excellent care, for Russia was paying the bill.

MR. M. N. BAKER.* The incompleteness of our typhoid statistics is notorious and extremely unfortunate, and we certainly should, all of us, use our influence to the greatest possible extent to make these statistics more complete. It would seem as though physicians above all men would be greatly interested in reporting cases of illness and death from the various communicable diseases. But I know from my experience in the last ten or twelve years as a member, and, later, as president of the board of health in a small town, that even where there is, as there is there, a very intelligent body of physicians, a body which is very glad to coöperate with the board of health and is continually coöperating with it in all respects, we have difficulty in getting prompt and complete reports.

In the matter of typhoid fever, however, I think our reports are quite complete, as we were unfortunate in years past in having some serious outbreaks of typhoid, thus impressing upon the physicians the importance of prompt and complete reports. One of the worst of these outbreaks emphasizes a point suggested

* Associate Editor, "Engineering News," New York City.

by one of the previous speakers. It was an out-and-out milk epidemic. In a town which then had a population of perhaps 11 000 or 12 000, we suddenly had 80 typhoid cases, followed by 13 deaths. All the cases were found after careful investigation to be attributable to the milk that came from a single dairy. The cans used for handling this milk were washed with the water from a well, which well was not very many feet distant from an outhouse at a higher level than the well; and this outhouse, it was subsequently ascertained, had been used by a young man, a son of the milkman, who had what may be called a walking case of typhoid, in fact I think it did develop into something more serious than a walking case of typhoid.

While we must not relax our efforts to safeguard our water and purify it when needed, it is important to all who have to do with the management of water works and the reputation of water works, that they should try to bring pressure to bear upon physicians and upon local boards of health to get more accurate and more complete vital statistics. We should not stop short with trying to see what part of the typhoid in a community is attributable to the public water supply.

One way in which I think we will have to broaden our health protective work is to include in our studies of typhoid hereafter, if we can find it feasible and practicable to do so, studies of the diarrheal diseases. I am convinced that while such studies will prove quite difficult, and the results may perhaps be ambiguous for the present, they will do this, if nothing else: they will show that in many of our communities diseases which really are typhoid are being reported as something else; and a careful comparative study of the diarrheal diseases in a given community, in connection with the returns for the same classes of diseases in other communities, will gradually throw a great amount of light upon this question and will contribute to the completeness of our typhoid statistics. I have recently had occasion to go over the vital statistics of a city which now has a population of nearly 20 000, for some twenty-five years past, and there are some things in connection with those vital statistics which are really very surprising, and which some day it is possible I shall have the pleasure of laying before the association.

Mr. George W. Wright. Getting back to Professor Mason's remarks on the relation between typhoid from well and stream waters, in the city which I represent, Norfolk, Va., we have had no typhoid cases from the city water, that is, none have ever been differentiated by the city bacteriologist. We have quite a number of typhoid cases in the city, and they are accounted for by the fact of the large floating population, and that there are many people who live at the beaches during the summer who, as a rule, drink water from wells, and it is claimed that they bring most of the cases to the city. That is the principal reason, I think, why we have a comparatively large typhoid fever rate in the city of Norfolk, and it is not due to the city water at all. With reference to the virulence of different cases, those who come from the beaches usually have severe cases, which would seem to bear out Professor Mason's theory.

Dr. Soper. Mr. Baker has said that it is well worth while to investigate and take account of the diarrheal diseases which are not positively pronounced to be typhoid, because he thinks that in many cases such diseases will be found to be typhoid. This is precisely my own view. The fact that a great deal more typhoid fever exists in any locality, where some cases are known, has been very conclusively settled by an investigation made by Koch, who embodied the results of his study in a lecture which he delivered before the Kaiser Wilhelm Academy, Berlin, November 28, 1902.

I have no doubt that before many of the great typhoid epidemics have broken out, there have been distinct warnings in waves of diarrheal diseases that have passed over the communities and that these signals of danger could have been discovered and interpreted by any one who had the disposition to note them. At Ithaca there was the well known "Ithaca fever" or "Freshman fever," which attacked large numbers of the freshman class at Cornell University every year. When the typhoid epidemic broke out in 1903, it was at first declared to be nothing but the "low form of fever" which had been experienced every year in the fall. At Butler, Penn., small waves of typhoid had passed over the city before the great epidemic of 1903–4. At Watertown, N. Y., several distinct and recognized epidemics occurred before the extensive outbreak of 1904.

The warning signals of typhoid epidemics are probably flying in many cities to-day. It behooves water-works people to look for them and when discovered to take those measures of precaution which alone can be successful in averting disaster. It is unnecessary to point out the nature of the precautions. The conservation of the purity of the water supply by the sanitary protection of the water-sheds, and the purification of waters of doubtful quality by means of filtration, are among the most firmly established measures of safety which experience offers. That such work must be done in the best possible manner, if done at all, it is not necessary to point out to the members of this association.

MR. G. C. WHIPPLE.* The remarks of Dr. Soper lead me to say a few words in corroboration of his statement that epidemics of typhoid fever are often preceded by distinct warnings. In the paper on typhoid fever which I had the pleasure of reading before this association last winter † I mentioned the case of a town in Maine where the use of a polluted water at the time of a severe fire was followed by an epidemic of diarrhea. No attention was paid to this warning, and a few months later, when a second fire occurred, the same polluted water was again used, and this time it resulted in an epidemic of typhoid fever which gave rise to the great epidemic of typhoid fever which occurred in the Penobscot Valley.

It has been stated that typhoid fever may be due to other causes than water. It is well known, of course, that typhoid fever is found in many cities and towns where the water is absolutely above suspicion. I have recently had occasion to tabulate, for various states, the typhoid fever death-rates in certain cities and towns where the water supply was taken from driven wells. In these cases I found that the rate was, in general, quite low, much lower than in those cities and towns which used surface waters liable to pollution. It was interesting to notice that of the cities and towns which used ground water those in the northern part of the country had lower typhoid fever death-

* Consulting Engineer, New York City.

† The Kennebec Valley Typhoid Fever Epidemic of 1902–3. By George C. Whipple and Ernest C. Levy. JOURNAL, June, 1905, vol. 19, p. 147.

rates than those further south. This is shown by the following figures:

State.	Number of Cities and Towns Averaged.	Number of Years Averaged.	Average Typhoid Fever Death rate per 100,000.
Maine	2	5	6.4
Massachusetts . . .	23	5	15.8
Connecticut	4	5	9.5
New York	13	5	24.7
New Jersey	10	1	20.5
Pennsylvania . . .	5	1	31.8
Ohio	22	5	32.4

It is a well-known fact, shown by the census bulletins, that typhoid fever is much more abundant in the South than in the North, and it is interesting to notice that these figures correspond with this fact, indicating that other causes than water supply are more operative in the South than in the North.

Mr. Bemis. May I ask Mr. Whipple what the general average death-rate was in those cities whose water was pure?

Mr. Whipple. I cannot give you exact figures, but my recollection is that in the New England States it averaged about 10 per 100 000, while in New York and New Jersey it was nearer 20. A little farther south it was still higher. The data for the southern states are very meager, perhaps at an average figure we might take 15 per 100 000.

Dr. Mason. It must be carefully borne in mind that the typhoid death-rates to which Mr. Whipple has referred show the ratio of deaths to number of people living, both well and ill. The rates to which I have asked attention indicate the ratio of severe cases of the disease to the number of people attacked, — two very different propositions.

THE MUNICIPAL WATER-SOFTENING PLANT AT OBERLIN, OHIO.

BY W. B. GERRISH, SUPERINTENDENT OBERLIN WATER WORKS.

[*Read September 14, 1905.*]

The dweller in the New England cities uses the soft water supplied without a thought that any city is furnished with any other. True, some supplies may be polluted, but when that is remedied, his anxiety ceases.

The granite hills of New England furnish a very different supply from that found in the glacial till and limestone formation of the Middle West. Many cities in this region furnish their inhabitants with a water so hard that there is a lingering doubt in one's mind whether the sticky scum left from the soap is not worse than the dirt the soap is supposed to remove. Burned-out water backs and lime-coated crockery are other inconveniences, while the steam user and laundryman are in constant trouble.

It was a common remark regarding the Oberlin water, that it was good water, if it were only not so hard.

It is a surface water from an agricultural district and shows a low bacterial content, but, like all surface water supplies, it is liable to specific contamination. The water was so hard, however, that with possibly half a dozen exceptions each family was provided with a rainwater supply in addition to the city supply.

The writer was familiar with the fact that thousands of industrial softening plants were in existence and the query arose, why not soften the municipal supply? Besides, the chemical treatment of water dates back into hoary antiquity, for nearly three thousand years ago Elisha sweetened the bitter waters of Jericho by treating with sodium chloride. (2 Kings 2: 19–22.)

The situation at our works was such that a small reservoir, constructed when the works were built, could be used as a settling basin and the water could be delivered to it without extra pumping.

While studying on the matter, we were fortunate enough to meet Mr. C. Arthur Brown, who had had considerable experience in industrial water softening, and he assured us of the practicability of the scheme. The matter was presented to the water board and they were favorably impressed.

This board, by the way, was composed of unusual men to hold such a position in public affairs. One was a professor of natural science and one was a professor of chemistry in the college, while the third was to be common pleas judge. Two of the board have died within a year, but they lived long enough to see the successful completion of the work.

Realizing that an untried field of water treatment was being entered upon, every point was carefully examined. Plans from two of the builders of industrial softening plants were sought, but both required the extra pumping of the water. Both plans were rejected for this reason and the plan submitted by Mr. Brown, which did not require extra pumping, was adopted.

The small reservoir, shown in Plate I between the storage reservoir and the pump well, and having its water level some six or seven feet lower than the water in the storage reservoir, was cleaned and paved with brick. It was also divided along its minor axis by a concrete wall, making two settling basins of 330 000 gallons capacity each, the average daily consumption being one half that amount.

In the process of treatment, the raw water, to which the chemicals have been added, passes through a mixing box, and enters the bottom of the first settling basin. It is then drawn from the top by a float arm, and the water enters the bottom of the second settling basin. It is again drawn from the top and enters the pump well. It is then pumped to the standpipe, and on its way down passes through ordinary sand pressure filters.

Taking up the various parts in detail we have:

Soda Tanks. Two soda mixing tanks, 8 feet high by 4 feet in diameter, containing mechanical agitator for mixing the soda solution, and a control tank, 2 feet high by 3 feet in diameter, which is supplied from the mixing tanks through a ball cock and then delivers the soda solution at a uniform rate.

Lime Tank. One lime tank, 14 feet high by 10 feet in diameter, containing a mechanical agitator.

Both lime and soda tanks are of Louisiana cypress and were purchased of the New York Continental Jewell Filtration Company.

Motor. The power for the agitators comes from a Pelton water motor. The water used is softened water, but not filtered, and after passing the motor enters the bottom of the lime tank and becomes the lime water for treating.

This much of the apparatus is in the rear part of the pumping station.

Mixing Box. This box is 2 by 2 feet and 40 feet long, and contains baffles. It is made of open-hearth steel. It is buried under ground with the top at the level of the water in the settling basins when full and extends from the boy to the man in the picture. It is water tight and is under a little pressure.

Behind the first baffle the lime water is admitted and behind the second baffle the soda solution enters.

Distribution Pipe. The chemically charged water from the mixing box enters the bottom of the first basin through an 8-inch galvanized wrought-iron pipe 40 feet long and containing a row of 1-inch holes 6 inches apart.

A float arm draws the clearer water from the top of this basin and it is distributed along the bottom of the second basin through a similar pipe containing ¾-inch holes.

Filters. The lower section, 40 feet, of our standpipe is of stone, as shown in Plate II, and in this are two 7 by 7-foot pressure filters.

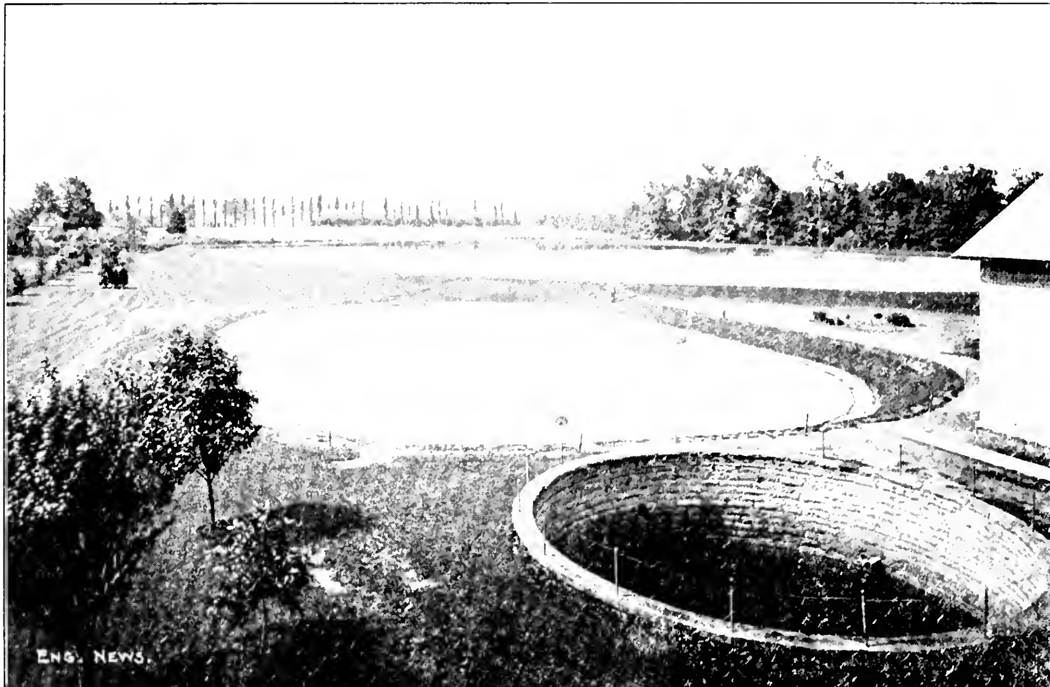
Operation. The man who attends to the water-works grounds also attends to the treating. Every three hours he weighs out the amount of soda required for a three-hour run and charges the empty soda tank, at the same time turning on to the control tank the soda tank previously charged.

Similarly, he weighs out and slakes the amount of lime required and runs it into the lime tank. This does not give a water of exactly uniform strength, as immediately after charging the lime water is somewhat stronger than at the close of the three-hour period, but the difference is not great.

The treating is done in from six to nine hours each day.

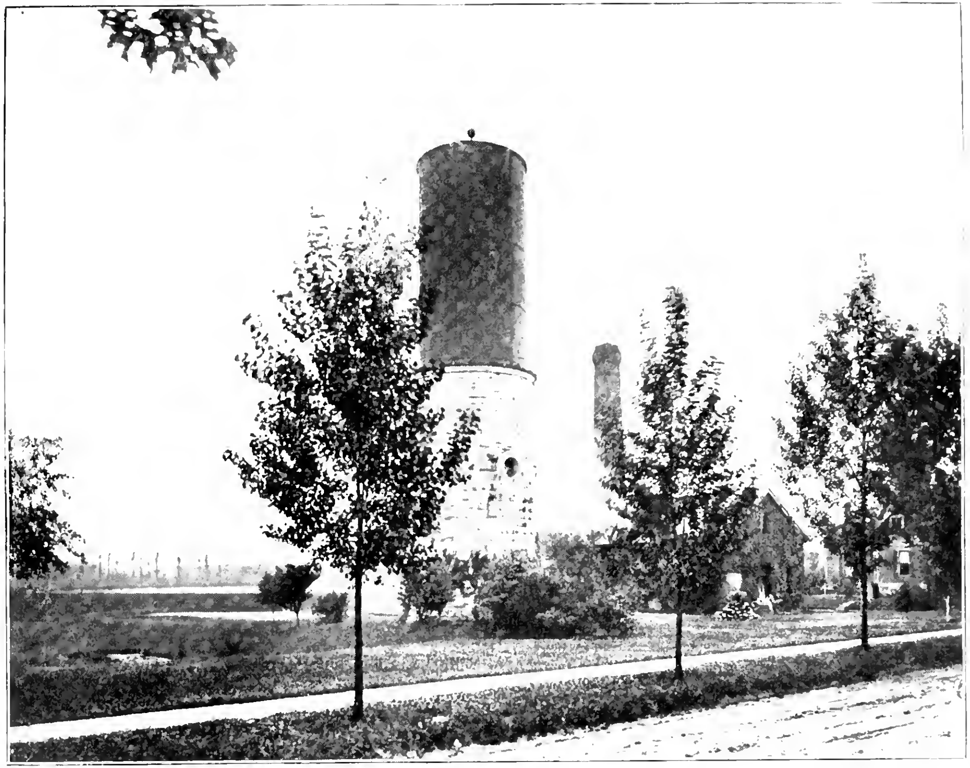
Water. As before stated, the water is a surface water, gathered

PLATE I.



SETTLING BASIN AND STORAGE RESERVOIR, OBERLIN WATER WORKS.

PLATE II.



STANDPIPE, OBERLIN WATER WORKS.

about six miles from town and conveyed in a vitrified conduit which, in spite of careful cementing, leaks water in dry weather and admits ground water in wet weather. The soil being a glacial till, full of limestone pebbles, renders the water very hard.

The analysis of the water in summer and winter is quite different, as is shown in the following determinations:

GRAINS PER U. S. GALLON.

	April 27, 1903.	Jan. 15, 1904	Laboratory Treatment of Second Sample.
SiO_2	.41	.79	.12
$Al_2O_3Fe_2O_3$	.09	.15	.02
$CaCO_3$	7.15	13.69	1.07
$MgCO_3$	.46	.50	1.40
$MgSO_4$	4.14	9.85	
NaCl	1.17	1.33	1.30
Na_2SO_4	.57		11.59
Organic and volatile		2.21	.18
Alkalinity	8.16	14.30	2.70
CO_2 (free and semi-combined)	3.40	7.40	

Chemistry. The hardness of the water is caused by the rain water dissolving the "chemicals" from the soil upon which it falls. These chemicals are the carbonates and sulphates of lime and magnesium.

The process of softening depends first on the principle that carbonates are only partially soluble except in the presence of free CO_2, and second, that the sulphate of magnesium can be decomposed into insoluble calcium carbonate and magnesium hydrate, leaving a soluble sodium sulphate which does not harden the water, by adding sodium carbonate and calcium hydrate.

The reaction is as follows:

$$m(CaCO_3 + CO_2) + n(CO_2) + mn(CaO) = 2mn(CaCO_3).$$

$$MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3.$$

The sulphates react as follows:

$$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3.$$

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 = CaCO_3 + Mg(OH)_2 + Na_2SO_4$$

And thus Epsom salt in the raw water is changed to Glauber salt in the treated water.

To the popular mind it seems to be such a paradox that we

should *add* chemicals to the water and have less chemicals in the water at the last than at the first.

However unbelieving they may be as to the theory, the results they like.

During 1904, determinations of calcium and magnesium were made at various times with the following results:

Date (1904).	Water.	Grains per U. S. Gallon.				
		$CaCO_3$.	$MgCO_3$.	$CaSO_4$.	$MgSO_4$.	Alkalinity.
June 27	Natural	10.14	.68		6.54	10.95
	Softened	2.03	1.36		.33	3.65
July 18	Natural	10.05		.73	7.53	10.05
	Softened	2.64	.38		.83	3.10
July 20	Natural	9.95		.55	7.35	9.95
	Softened	2.95		.79	.84	2.95
July 26	Natural	9.50		.43	6.96	9.50
	Softened	3.30		.26	.72	3.30
July 28	Natural	9.20		1.01	6.87	9.20
	Softened	2.16	2.13		.57	4.70
Aug. 1	Natural	10.30		.99	7.74	10.30
	Softened	2.78			.54	2.80
Aug. 4	Natural	9.45		3.15	8.10	9.45
	Softened	3.00	.50		.03	3.60
Aug. 11	Natural	9.66	.58		7.29	10.35
	Softened	2.87	.48			3.55
Aug. 16	Natural	9.82	.67		7.08	9.90
	Softened	2.00	.96			3.15
Aug. 23	Natural	10.00	.17		7.65	10.20
	Softened	2.11	.24		1.54	2.40

Since the spring of 1905, with a better knowledge of how to control the treatment, we have been able to keep the alkalinity to less than three grains per gallon most of the time, with no permanent hardness as determined by Hehner's method.

Control. The proportioning of the chemicals for such work is a matter requiring very careful attention, for there is no process of water treatment which would so soon become a byword and a hissing as the softening process if carelessly operated.

The soap determination is unsatisfactory, for it is not delicate enough even if there were no trouble from magnesium, and we find it impracticable to remove all the magnesium without leaving too high caustic alkalinity.

Neither is the control with dilute silver nitrate sufficiently delicate. In ordinary industrial work, if the water should become so alkaline as to give a brown color with silver nitrate the worst feature would be the loss of chemicals, but if the superintendent of a municipal plant should furnish such water it would mean the loss of his official head.

The water should never be allowed to give even a straw color with silver nitrate. But from a straw color through a very slight cloudiness to white is a long range.

The most satisfactory control for our particular water is to titrate the treated water taken from the center of the distribution system with $N/50 H_2SO_4$, using phenolphthalein first as an indicator and then methyl orange, and the ideal treatment gives the following results, using 58.38 cc. of the water, or a miniature United States gallon.

$1.8+0.8=2.6$ total alkalinity, provided the soda treatment is adjusted to give no permanent hardness.

If the results are

$(1.8-)+(0.8+)$, then too little lime is used.

$(1.8+)+(0.8-)$, then too much lime is used.

The above is entirely empirical.

At the same time that the lime is being adjusted, the soda is controlled by Hehner's method as follows:

Take 58.38 cc. of the water and add $N/50 Na_2CO_3$ in excess. Evaporate to dryness. Wash with boiling water and filter. When cold, titrate as before, using methyl orange as an indicator.

If the amount titrated back is less than the alkali added, the difference indicates the amount used in precipitating the calcium and magnesium, which produced permanent hardness. If the amount titrated back is greater than the amount of alkali added, then it indicates that the water contains alkali carbonates which have been reckoned as alkalinity, or in other words, too much soda has been added.

Lime. The Ohio limes are high in magnesium and contain only 50 per cent. of CaO, so that they are not adapted to this use. We get a lime from the Mississippi River containing about 90 per cent. CaO, and by buying it in bulk, get it at the same price as the Ohio lime in barrels.

Soda. In the purchase of soda there is little choice.

The maximum amount of lime used the past year was 17 grains per gallon of water and the minimum was 6 grains, while the maximum of soda was 6 grains and the minimum was 2 grains per gallon.

Bacteriology. While we had a water supply that had never been suspected of causing a case of sickness, still it was liable to specific contamination. It was the desire of the board to provide, if possible, against such a possibility.

When a coagulant like alum or lime and copperas is used it is the idea that the precipitate formed will entangle the bacteria and carry them down. It will at once be seen that if the small precipitate formed by these chemicals will be so effective, how much more effective must be the heavy precipitate formed by the lime and soda ash.

By the accompanying table it will be seen that 90 per cent. of the bacteria are removed in the first basin, while the water delivered to the village contains less than 5 bacteria per cubic centimeter — a result not attained elsewhere to my knowledge.

REPORT OF G. R. PATTON OF BACTERIA FOUND PER CUBIC CENTIMETER.

Date (1904).	Storage Reservoir.	First Basin.	Second Basin.	Hydrant Water.	Hydrant Water.	COLON BACILLI. Storage Res'voir.	Hydrant Water.
Nov. 28	440	50	10	4	6		
" 29	800	60	30	6	0		
" 30	300	50	37	12	6		
Dec. 1	320	50	20	16	17		
" 2	160	30	20	4	7	Yes	No
" 5	300	25	12	6	5		
" 6	350	12	2	4	2	Yes	No
" 7	Error	15	7	1	2		
" 8	300	156	6	1	3		
" 9	300	11	11	5	5	Yes	No
" 12	Lost	20	5	1	4		
" 13	250	20	10	6	6	Yes	No
" 14	500	12	10	1	0	Yes	No
" 15	100	10	7	1	4		
" 16	100	10	1	0	2		
Average,	370.76	37.10	12.73	1.53	4.60		
Per cent. reduction,		89.91	96.56	98.78	98.75		
Found by E. G. Horton, of State Board:							
Aug. 18	192		33			Yes	No

In the spring the bacterial content of the raw water rises to several thousand per cubic centimeter, but the filtered water shows almost as good results as in the above table.

Troubles. But does not the water taste badly? Well, if there was ever a case where the popular imagination ran riot it was in the chemical treatment of water. When the treatment began, there was hardly an imaginable taste not detected, and sickness of every description was attributed to it. Time has wrought wonders in the public palate, which has now become accustomed to the absence of the chemical substances formerly in the water. There is still an occasional rumble from the first storm, but the general opinion is one of high appreciation. Rain water supplies are being rapidly abandoned, and there is a decided increase in our receipts — in fact, an increase much more than the increase in the cost of the operating expenses.

The holes in the distribution pipe in the bottom of the first basin become filled with a hard formation of lime which needs to be poked out every week. In six weeks the holes will become entirely filled.

The holes in the distribution pipe in the second basin will be filled in as many months.

This tendency of the treated water to form deposits, especially where there is a constriction and consequent rapid flow, is the one thing about the process to cause anxiety. Our treatment was started December 28, 1903, and has been continuous ever since except the month of March, 1904, when some uncompleted work was finished. In October, 1904, the mixing box was opened and there was a soft deposit on the sides from $\frac{1}{4}$ to 1 inch in thickness, and in contact with the steel a very hard deposit about $\frac{1}{16}$ inch thick. Whether this hard deposit will increase or whether the soft deposit will wash off with the flow, time will tell.* The distribution pipe in the first basin and the vitrified pipe connecting it with the mixing box have been cleaned several times of an inch or more of a hard deposit. The sides of the basin, whether of stone, brick, or concrete, show no incrustation, while the float

*On September 21, 1905, the mixing box was again opened. Sufficient deposit of lime was found at the ends of the baffles and at the outlet to nearly cut off the flow. We may therefore, expect to clean the mixing box once a year.

and float arm of galvanized iron show a hard deposit an eighth of an inch thick. Closing the gate between the two basins requires considerable work. There is very little trouble in the second basin. After over a year's use the pump cylinders were opened and we found them beautifully white, but no appreciable deposit.

The precipitate in the first basin amounts to about a foot a month, while in the second basin only about 4 inches accumulated in twenty months. This precipitate is emptied in a creek by gravity.

Upon the sand of the filter there forms a coating of the carbonate of calcium and magnesium, so that after fourteen months' use the effective size changed from .37 mm. to .55 mm. and the uniformity coefficient from 1.62 to 2.0. This makes $\frac{4}{5}$ of the bulk carbonate and $\frac{1}{5}$ sand. The bulk of the sand of the filters has been increased so that is was impossible to operate the rakes, and a foot of sand has been removed from the filters. In time the sand will have to be cleaned or new sand put in.

The filters are washed twice each week by reversing the current and stirring with rakes operated by hand power. Often there is no loss of head before washing, but sometimes there is a loss of two feet. When dirty it takes four minutes to wash a filter, and requires about 2 000 gallons of water.

There is no " after precipitation " noticed except in two cases where the water is warm and allowed to stand in that condition for a long time.

A careful watch is being kept on the meters to see if a deposit of the carbonate of lime forms on the inside. In no case thus far has the writer been satisfied that any harm has been done. If there should be trouble it could be easily remedied by putting enough CO_2 into the water to fix the carbonates, as is usually done where lime only is used for softening.

A curious phenomenon has been noticed in the hardness of the raw water in the spring. After the first decidedly warm days came in April, when no water was being admitted to the storage reservoir, in four days the water changed in alkalinity in the ratio of 31 to 18, and a few days afterward the permanent hardness changed as much and as suddenly. The semi-annual " overturn " is the only explanation we can offer.

Remarks. There seems to be quite a disposition on the part

of manufacturers of softening machines to show how quickly the water passes through and how little tankage is required. The writer's observation has led him to the conclusion that, for our water at least, the softening process is one requiring considerable time. As before noted, each settling basin contains twice the amount of a day's consumption, but at the time the following samples were taken (August 23, 1905) the consumption was only one third of the capacity of each basin.

Sample.	Grains per U. S. Gallons. Alkalinity with Phenol.	Alkalinity with Methyl Orange.	Total Alkalinity.
Raw water			12.0
Basin No. 1	3.3	3.2	6.5
Basin No. 2	3.0	2.1	5.1
Past filters	1.9	0.8	2.7
Center of system . .	1.7	0.8	2.5

This series of determinations shows the improvement of the water by standing and also the effective work of the filters.

When we are using more water there is always an improvement of .5 or .6 grain of alkalinity per gallon between the water as it passes the filters and the center of the distribution system, instead of only .2 as here shown. We should therefore conclude that to reach the best results there should be about six days of sedimentation before filtering.

The action of the soda seems to take place entirely in the first basin, as a sample from there shows the same results when tested for permanent hardness as one taken from the center of the distribution system.

The query which rises in the mind of every water-works manager is, Does not the process cost too much to be practicable? In a system that requires you to pour four gallons into the bung to draw one at the spigot there is no question that it would be financially ruinous, but in a system that can account for one half or more of the water pumped it certainly is practicable. For water such as ours the chemicals cost one cent per thousand gallons delivered, while labor, interest, and depreciation will probably add a cent and a half more, making the cost of softening the water delivered to the pumps 2½ cents per thousand gallons.

The cost can be but very little reduced from this, no matter how much water is treated.

If half of this is delivered through the meters it would add to the present cost in any such system five cents per thousand gallons — a sum which any community can afford to pay for water of such a quality. In our own system, by shutting off the sewer flush tanks and horse troughs, the use and consumption between 10 P.M. and 4 A.M. is only 500 gallons per hour, with 10 miles of mains and 900 taps, but we are not able to account for as high a percentage of the total amount pumped as we would like. Every water-closet in town is metered, even in schoolhouses and other institutions having free water. The result is that 80 per cent. of all taps in use are metered.

To a town which is obliged to purify its sewage there is an additional advantage in the use of the softening process. As has been noted, the water is in general alkaline to phenol to the extent of about 2 grains per gallon. For precipitation with copperas it is necessary to have the water alkaline. During two summers now we have used copperas for precipitating the sewage and have gotten very satisfactory results. The sewage farm has been entirely free from odors and the effluent which enters what is practically a dry run causes no nuisance. It was found, however, that the water in changing to sewage absorbed enough CO_2 to become neutral and it is necessary to add some lime.

The use of the softened water has been entirely satisfactory in house aquariums and the goldfish have done well in it, as is not the case sometimes when other coagulants are used. In blowing dead ends it is found that there is no odor to the water.

The possibilities of the lime-soda process for municipal use seem to be little appreciated as yet, but the time will doubtless come when it will be the means of solving some of the vexing problems of water supply in the middle West.

DISCUSSION.

Mr. Kenneth Allen. I should like to ask what the capacity of the plant is and what it costs.

Mr. Gerrish. Our consumption averages 165 000 gallons, and the cost was about $12 000.

Dr. Frederick S. Hollis.* I think we are especially indebted to Mr. Gerrish for the description which he has given us of the water-softening plant at Oberlin. We who live in New England can have little conception of the inconvenience of having a supply of water as hard as that of some of the towns of the middle West. Our trans-continental lines have been foremost, perhaps, in erecting softening plants for the purpose of preventing scale from forming in their boilers, and many of our industrial plants, especially where dyeing is carried on, are obliged to soften the water which they use because the lime salts will in many cases give a different color with the dye from that which is desired, and sometimes they will change the texture of the fabric somewhat; but I do not recall any other such plants in connection with domestic supplies.

The inconvenience of having a domestic supply so hard as it is in some of the western states is largely because of the power of such water to combine with soap. The expense of softening the water per 1 000 gallons has been given, and I should think that would probably be more than saved to the community in the saving in soap necessary for washing and domestic use. Then another thing I have noticed, especially in Ohio, where I first had experience of this kind, was that in order to soften this water for domestic use, with as little soap as possible, a soap that was extremely strong, that is rich in alkali, was used. I well remember what disastrous effect such soap had on the skin, and I can imagine what its continuous use must be on the fabric of clothing.

In New England the water in most of our city supplies is only moderately hard. In the Connecticut valley, — and by the Connecticut valley I mean the line of the old Jura-Trias valley bounded by the sandstone formation, — some of the ground water is extremely hard, but most of our supplies are not of the nature described by Mr. Gerrish, and we do not realize the importance of the problem until we go outside of New England.

Mr. G. C. Whipple.† I am extremely glad that Mr. Gerrish has presented this paper, for the plant at Oberlin was the first municipal water-softening plant erected in the United States,

* New Haven, Conn.
† Consulting Engineer, New York City.

although the one at Winnipeg, Canada, antedates it. We are certainly very fortunate in having such a complete description from the superintendent.

There is one point that Mr. Gerrish mentioned which interested me considerably, namely, the time element which enters into the chemical reactions involved in the softening of water. Mr. Gerrish rightly says that these reactions do not take place instantaneously, but require a certain amount of time. It is due to the slowness of these reactions that "after deposits" of calcium carbonate occur in the pipes and filters. These "after deposits" are often very troublesome. You will recall that when lime is added to water it acts on the calcium bicarbonate, changing it to calcium carbonate, and on the magnesium bicarbonate, changing it to magnesium hydroxide. Experiments which I have made recently have shown that the magnesium reaction takes place very much more rapidly than that of calcium, and it is for this reason that most of the "after deposits" are composed almost entirely of calcium carbonate and contain almost no magnesia. While it is true that most of the precipitate settles in about six hours, it takes several days for the final reaction to be complete. An examination of several plants which differ considerably in the time allowed for the chemical reaction shows that practice follows theory in this matter. Those plants providing for only a few hours' sedimentation do not give as good efficiencies as those where greater time is allowed. In the plant at Oberlin the final alkalinity is often as low as 30 parts per million. At Winnipeg, where the time for chemical reaction is less than two hours, the resulting alkalinity is about 80 parts per million. Other plants, intermediate between these two, give intermediate results.

The "after deposits" which take place on the sand grains of the filter and in the distribution pipes may be prevented by what is called "recarbonation," that is, the artificial addition of carbonic acid. This unites with the normal calcium carbonate and the magnesium hydroxide and causes them to be changed to bicarbonates which are soluble. In industrial water-softening plants recarbonation is seldom practiced, but if municipal water-softening plants are to develop, as seems likely, this matter must receive very careful attention.

MR. ROBERT S. WESTON.* Such papers as this excellent one by Mr. Gerrish are most timely. Very little has been said in this country concerning the softening of municipal water supplies. There are many cities in the country in which there is such a waste of soap that if opportunity could be given in those cities for the writing of such a descriptive paper as this, a great step in municipal economy would have been taken.

Referring to the point which Mr. Whipple has spoken of, namely, the period of sedimentation thought necessary to produce satisfactory results, one naturally asks if the same effect could not be produced by active mixing or stirring, or by some other similar procedure. It might be cheaper to do the work in this way than by a long period of storage in subsiding basins, where mixing must be by diffusion, although it must be recognized that even under the most favorable conditions the action between the added chemicals and the salts in the water is not an instantaneous one, but one requiring considerable time.

The speaker would like to ask Mr. Gerrish if the precipitation in the plant at Oberlin is so complete as to prevent practically the after-precipitation of lime salts in the underdrains of the filters. This is mentioned because a similar difficulty has been met with in Europe in a good many cases, probably because the process has been hastened unduly by not providing such ample storage as has been arranged at Oberlin. In these cases the water is not adequately treated; the filters become incrusted with salts of lime, clog, and are condemned; whereas, were ample provision made for removal of the precipitate the plants would probably be entirely successful. The speaker remembers, for example, that at Canterbury, England, where less than six hours' treatment is provided for, the after-precipitation of lime frequently causes annoyance, especially at times of unusual draft upon the supply.

MR. GERRISH. I will say that this matter of how much time would be required did not come to my notice until the month of August. A great many of our people move out of town during that month, and our consumption is very light then, so we had an opportunity to give the water about six days of precipitation.

* Sanitary Expert, Boston, Mass.

and by that means, as I said, I very seldom got any decrease in alkalinity between the filters and the taps in the middle of the city, whereas previous to that I always got a difference of .5 or .6 of a grain. From that I concluded that six days in the case of our water would be the maximum time required for complete precipitation. If we could give the water six days' precipitation all the time, I don't believe we would have any trouble with the filter, for then there would be no change in the water after it left the filter.

I would say, in regard to plants of this kind, that the plant at Winnipeg uses lime only; there is a plant at Freeport, Ill., for taking out iron, which uses lime only. So far as I can find out, the Oberlin plant is the first plant, either in this country or abroad, for a municipal supply using lime and soda.

Mr. Weston. I should like to ask Mr. Gerrish one more question. Has there been any great decrease in the amount of soap used in the town? Have the grocers commented on it, for example?

Mr. Gerrish. I went into one grocery store and made that inquiry, and they seemed so entirely at sea as to what I meant when I asked the question that I really lost heart about getting any data of that kind. I may say that in my own family I have noticed a very decided improvement in that regard.

SOME FEATURES OF ESTIMATING STREAM FLOW IN NEW ENGLAND.

BY H. K. BARROWS, DISTRICT HYDROGRAPHER, UNITED STATES GEOLOGICAL SURVEY, BOSTON, MASS.

[*Read September 15, 1905.*]

The object of this paper is to discuss some of the features of estimating river flow in the New England states as now being carried on by the Hydrographic Branch of the United States Geological Survey, and, in general, to better acquaint the members of this association with the nature of the work that is being done by this bureau of governmental service.

The United States Geological Survey has been in existence since 1879, as one of the branches of the Department of the Interior. Its work has covered a broader field than that of geology ever since the beginning, and in some respects its name is therefore misleading. The Geological Survey has five subdivisions, as shown by the following table:

Administrative.	Executive.	
	Disbursements and accounts.	
	Library.	
Geologic.	Geology.	
	Alaskan mineral resources.	
	Mining and mineral resources.	
	Chemical and physical researches.	
Topographic.	Topography.	
	Geography and forestry.	
Hydrographic.	Hydrography.	Districts: (1) New England, (2) New York and Great Lakes, (3) Middle Atlantic States, (4) Southern States, (5) Central States, (6) Texas, (7) Western States with numerous subdivisions.
	Hydrology.	
	Hydro-economics.	
	Reclamation service.	
Publication.	Editorial.	
	Engraving and printing.	
	Documents.	

Perhaps the one which has been best known to engineers in the past is the Topographic Branch, which will eventually complete a topographic map of the United States. This work is proceeding slowly, and, at the present time, perhaps about one third of the whole country is thus mapped. The Hydrographic Branch has been a distinct feature of the Survey since 1888, and now consists of several subdivisions, as shown, at the present time it being one of the most important divisions of the Survey.

It is interesting to note the growth of the Geological Survey as shown by appropriations. Thus, the first appropriation in 1879 was \$106 000; while for the last fiscal year something over a million and a half dollars were appropriated — the larger items being as shown in the following list:

Topography	\$300 000
Geology	150 000
Alaska	60 000
Hydrography	200 000
Chemical and physical researches	20 000
Mineral resources	50 000
Engraving and printing maps	100 000
Surveying forest reserves	130 000

The chief work of the Hydrographic Branch has been that of estimating river flow, and, in general, investigating the water supply of the country. For many years all of the work of this branch was carried on in the West and only recently were begun the systematic measurements of river flow east of the Mississippi River.

The first work of this kind in New England dates back to 1900, when a gaging station was established upon the Connecticut River at Orford, N. H., this being still in operation at the present time. At about the same time another station was established on the Housatonic River at Gaylordsville, Conn. These stations were established with the idea of getting some general information on the subject of river flow in this vicinity. The first systematic measurements on a considerable scale began in 1901 in the state of Maine, and were made possible through the coöperation of private parties. This was in the Kennebec River valley, where a number of the water-power users and lumbermen desired to ob-

tain some reliable figures of flow of the river and its tributaries, and, in general, such information as would be of use in developing and maintaining water powers. This work was done by the United States Geological Survey in coöperation with these private parties, and, as government funds became available, in the course of the next year measurements were started on some of the other important rivers of the state. The state, too, at the next session of the legislature, recognized the value of the work by making an annual appropriation for hydrography, which has been continued up to the present time, and largely increased during the past year. In 1903 the United States appropriation became sufficient to permit of this stream work being extended to the other New England states, and this was first done in the states of New Hampshire and Vermont. About this time New Hampshire became interested in the hydrography of the White Mountain region in connection with the investigations of the State Forestry Commission, and a state appropriation was made, and coöperative work begun with the Geological Survey in a study of river flow in the White Mountains, particularly with regard to the effect of deforestation upon run-off. This work is still going on, and it is hoped that some definite results will, in time, be obtained, although, of course, such a problem is not one capable of an immediate solution. In the lower New England states the work of stream measurement dates back to the spring of 1904. The present location of stations maintained by the Geological Survey is shown in the following table:

MAINE.

	Date Established.
Fish River at Wallagrass	July 29, 1903
Aroostook River at Fort Fairfield	July 31, 1903
St. Croix River at Sprague's Falls, Baring	Dec. 4, 1902
Machias River at Whitneyville	Oct. 17, 1903
Penobscot River at West Enfield	Nov. 5, 1901
East Branch, Penobscot River, at Grindstone	Oct. 23, 1902
Mattawamkeag River at Mattawamkeag	Aug. 26, 1902
Piscataquis River at Foxcroft	Aug. 17, 1902
Cold Stream at Enfield	June 14, 1904
Phillips Lake Outlet, Holden	July 7, 1904
Phillips Lake Outlet, Dedham	July 19, 1904
Kennebec River at The Forks	Sept 28, 1901

	Date Established.
Kennebec River at North Anson	Oct. 18, 1901
Moose River near Rockwood	Sept. 7, 1902
Roach River at Roach River	Nov. 10, 1901
Dead River near The Forks	Sept. 29, 1901
Carrabassett River at North Anson	Oct. 19, 1901
Sandy River near Madison	Mar. 23, 1904
Messalonskee River at Waterville	June 18, 1903
Androscoggin River at Dixfield	Aug. 22, 1902

New Hampshire.

Androscoggin River at Shelburne	May 30, 1903
Saco River at Center Conway	Aug. 26, 1903
Merrimac River at Franklin Junction	July 8, 1903
Pemigewasset River at Plymouth	Sept. 5, 1903
Contoocook River at West Hopkinton	July 9, 1903
Connecticut River at Orford	Aug. 6, 1900
Israel River (above South Branch), Jefferson Highlands	Sept. 2, 1903
Israel River (below South Branch), Jefferson Highlands	Sept. 2, 1903
Ammonoosuc River at Bretton Woods	Aug. 28, 1903
Zealand River at Twin Mountain	Aug. 29, 1903

Vermont.

Otter Creek at Middlebury	Apr. 1, 1903
Winooski River at Richmond	June 25, 1903

Massachusetts.

Connecticut River at Sunderland	Mar. 30, 1904
Deerfield River at Deerfield	Mar. 30, 1904
Ware River at Ware	Sept. 15, 1904
Quaboag River at West Warren	Oct. 25, 1904
Westfield River at Russell	Apr. 1, 1904
Westfield Little River at Blandford	July 13, 1901

Rhode Island.

Blackstone River at Woonsocket	Apr. 5, 1904

Connecticut.

Shetucket River at Willimantic	Apr. 4, 1904
Salmon River at Leesville	Mar. 16, 1905

Another object of the Hydrographic Branch is to publish estimates of stream flow made by private parties, where such can be

obtained of reliable character, and a considerable amount of information is placed on record in this way in the Annual Progress Reports of the Survey. At present, records of flow by private parties are obtained and published for the following points:

MAINE.

Penobscot River at Millinocket.
Kennebec River at Waterville.
Cobbosseecontee River at Gardiner.
Androscoggin River at Rumford Falls.
Presumpscot River at Sebago Lake.

NEW HAMPSHIRE.

Androscoggin River at Errol Dam.
Androscoggin River at Gorham.
Merrimac River at Garvins Falls.

MASSACHUSETTS.

Sudbury River at Framingham.
Merrimac River at Lawrence.
Lake Cochituate at Cochituate.
Nashua River at Clinton.
Ware River at Gilbertville.
Swift River at West Ware.

CONNECTICUT.

Connecticut River at Hartford.

Since 1903, a permanent force of hydrographers has been maintained for work in the New England District, and a branch office of the Survey is now located at Boston.

METHODS IN USE FOR ESTIMATING FLOW.

It is not the purpose of this paper to enter into details of the methods used, for these are explained very fully in the various Water Supply Papers that have been published. A brief outline, however, will perhaps be desirable. The principal method is that of estimating discharge by means of daily gage heights, and a discharge rating curve, based upon current meter measurements of flow at different stages, such that the discharge may be ascertained for any given gage height. There is required, then, a gage

suitably established, either of a permanent character or such that it can always be replaced according to the same datum, and some one to read this gage a sufficient number of times a day (usually twice), to give the mean height for the day. The gage most in use at the present time is what is known as the "Standard Chain Gage," which is capable of adjustment and frequently tested. The observer is some one living near by, perhaps a farmer, postmaster, or station agent.

To get a rating curve for the station, current meter discharge measurements are made by the hydrographer at different gage heights — any one measurement giving by means of soundings the area and by current meter observations the mean velocity — the product of these two factors being the discharge for a given gage height.

The current meter in most general use, and which has proven most satisfactory for river conditions, is the Price electric current meter.

The above method assumes that the discharge is always the same for a given gage height — condition of bed, banks, etc., of course, remaining the same. This is not strictly true, as the effect of slope of water surface is neglected, but, under the usual condition of rate of rise and fall, however, no great error is involved.

The other general method now used for estimating stream flow consists in utilizing water-power plants for the purpose. Thus, in many cases, it is practicable to use a dam as a weir, supplementing this, if necessary, by a record of gate openings and head on the wheels, and thus procuring data to compute the daily discharge.

LOCATING CURRENT METER STATIONS.

Perhaps the most important essential in locating a current meter station is that of obtaining what may be called a true or undisturbed gravity flow. It is not always easy to find this condition, and, in fact, upon some of the New England rivers it is well nigh impossible to find any great length of river that is not liable to effect from artificial causes. It is very evident that if back-water effect occurs from any reason, the usual relation between the gage height and discharge is at once changed. There are a variety of causes for this, the most common one being a dam downstream from the

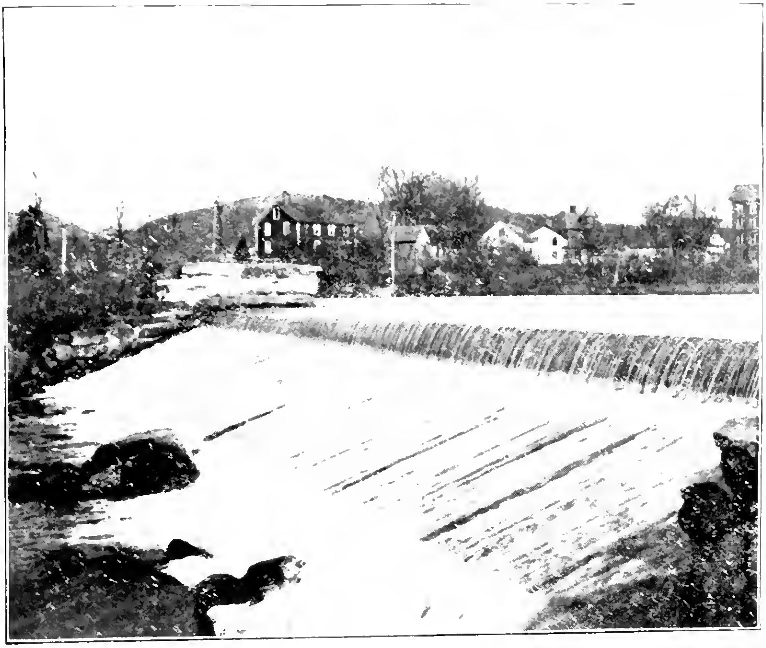


FIG. 1. U. S. GEOLOGICAL GAGING STATION AT WEST WARREN, MASS., ON THE QUABOAG RIVER.

FIG. 2. MAKING CURRENT METER MEASUREMENTS THROUGH THE ICE AT RICHMOND, VT., ON WINOOSKI RIVER.

gage and near enough to give this effect. Another source of back-water effect which often prevails is that of a stream entering the main river somewhat below the point under consideration, but of sufficient size and difference in distribution of run-off to change the conditions of flow in the vicinity of the station. Lakes or ponds, where considerable fluctuations of level exist at various times of the year, must, of course, be sufficiently distant from the gage to give no back-water effect. The matter of horizontal distance is not always the important thing in the above; for frequently back-water influence exists for many miles. Thus, as an illustration, on Otter Creek, the dam at Middlebury, Vt., probably affects the water level for a distance of twenty miles or more, while there are many cases where the influence of a dam is felt but a few hundred feet upstream. Back-water effect may also be caused temporarily by ice or log jams, and, of course, while such conditions prevail it is difficult or impossible to obtain good estimates of flow.

CHANNEL CONDITIONS.

The ideal in this respect would be a portion of a river with a permanent and smooth bed and with a straight channel both above and below the point considered, so that an even and regular flow could be obtained at all stages, and with a good velocity at low water, and not too swift for high-water conditions; moreover, the banks should be high enough not to overflow during floods. The above requisites are never met with completely, and it is usually a question of waiving some one or more of these desirable features and doing the best possible under the circumstances. In general, permanent conditions of the stream in the vicinity of the gage, although the bed be rough, are better than a smoother channel which, however, shifts or scours at times. The purpose for which the measurements are made usually has considerable weight in the selection of the station. Perhaps the most common way in which stream measurements are useful here in New England is in connection with water powers, and for such purposes it is the estimates of low water which are the most valuable. Consequently, under these conditions, the hydrographic features at low-water stages would have the most weight.

KINDS OF STATIONS.

A *bridge* is used whenever channel conditions are at all suitable in the vicinity, and these vary in convenience from the modern steel highway bridge, open and easy to work from, to the old covered wooden bridges, many of which still exist and which are often very difficult to utilize. Some of these latter have a narrow open space at the top, or a sufficient opening between flooring and bottom chord to permit of passing the current meter through, while in a few cases it is necessary to tear up a line of floor planks every time a measurement is made. The standard chain gage is best adapted for use at a bridge station, although frequently a staff gage can be readily placed on an abutment or pier. Railroad bridges of the deck type are often found which would make good stations as far as hydrographic conditions go, but cannot be considered on account of the danger involved in using them.

A *cable* with a suspended car is frequently a necessity where no bridges are available. In this case it is some times possible to fasten a chain gage to trees on the bank, or a staff gage to a bowlder. As the site for a cable station can be picked with the best conditions in mind, the results at such stations are usually of the best. The first cost of such a station is, of course, considerable, and, moreover, the cable and anchorages have to be carefully looked after and kept in repair to insure safety to the hydrographer.

A *boat* or *canoe* is frequently used in making current meter measurements. Under good conditions — no wind and not too swift a current — fairly good results can thus be obtained by the use of stay lines at both bow and stern. It is, perhaps, the most unsatisfactory method, although sometimes necessary where the expense of a cable would be too great.

Measurements are frequently made by *wading* and with excellent results. Very often a gaging station which would otherwise be useless at low water, owing to sluggish current, can be operated by finding some site nearby where good velocity conditions exist.

OPERATION OF STATIONS.

It is the practice to check up gages at least once a year with a level, and in some cases still more often. This is done by the

FIG. 1. WESTFIELD LITTLE RIVER, NEAR BLANDFORD, MASS. GAGE USED WITH CABLE STATION.

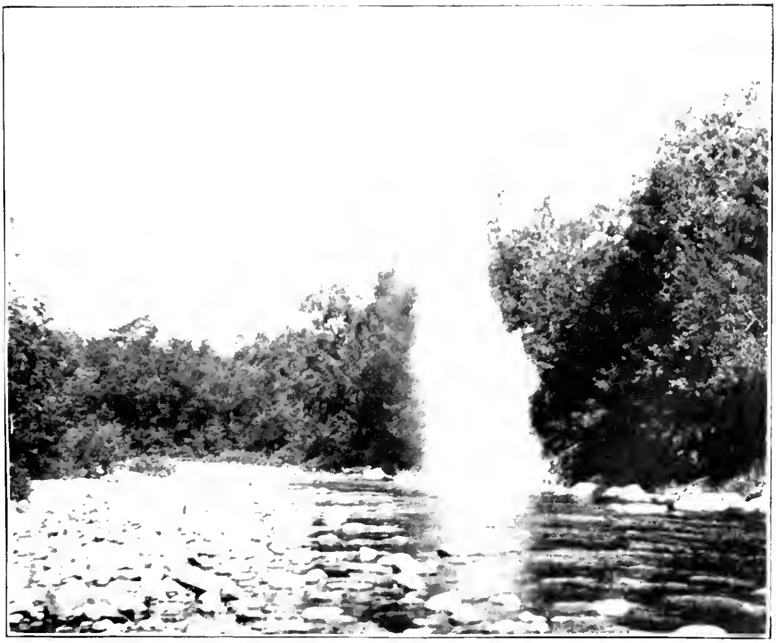


FIG. 2. WESTFIELD LITTLE RIVER, NEAR BLANDFORD, MASS. CLEARING UP CHANNEL WITH DYNAMITE.

use of permanent bench marks on shore referred to the gage datum. Whenever it is practicable some point on bridge or bank over the water is selected by levels also referred to gage datum, and, by measurement to the water surface with steel tape, used in checking gage readings. Where chain gages are used the chain is very frequently measured and correction made if necessary.

An old covered wooden bridge has been known to settle as much as 0.2 foot in six months, while frequently on modern structures no appreciable settlement occurs for years. The gaging station on Zealand River, near Twin Mountain, N. H., has required frequent attention, the gage being fastened to two trees on the bank, one of which occasionally settles, so that a total vertical change of 0.27 foot has occurred in the position of the gage since its installation about two years ago.

There are various causes which may at times prevent a good current meter measurement. Thus, if there is a rapid fluctuation in gage height during the measurement, poor results will be obtained, and where gagings are desired under such conditions, rapid methods must be used. For instance, velocity observations may be taken at one foot depth, and the soundings left until afterward. By taking a few vertical velocity curves just after the gaging is completed, the coefficient to apply to the observations at one foot depth may be determined.

Rapid fluctuations in height occur upon some of the Maine rivers owing to the use of stored water for driving logs, and while this is being done — from perhaps May to August — considerable care has to be taken in reading and interpreting gage heights, and quick methods used for gagings. Thus, on the Kennebec River at The Forks during the week of July 16–23, 1905, the average morning reading was 1.71, corresponding to a discharge of 1 125 cubic feet per second; while that at night was 5.59, which corresponds to about 8 775 second-feet. This is due solely to differences in gate openings at Moosehead Lake, some twenty-five miles away, and gives some idea of the amount of water being used for log driving.

Temporary obstructions, as log or ice jams below the gage, or an accumulation of logs at the gage, may absolutely prevent gaging. The Androscoggin, Kennebec, Penobscot, and St. Croix rivers and

their tributaries are especially apt to give trouble in this way during the log-driving season. Current meter measurements frequently have to be made while logs are running, but great care and watchfulness are required to do this without injury to the meter.

Anchor ice may, under certain conditions, form in the late fall and early winter before the rivers are completely frozen over, and make sufficient obstruction to affect gage readings. Thus, upon the Westfield River at Russell, Mass., on November 29, 1904, when the river bed was more or less coated with anchor ice, at gage height 0.99 a current meter measurement gave a discharge of 196 second-feet. The estimated discharge from the rating curve at this gage height is 250 second-feet, and the percentage error of this measurement of some 28 per cent. is probably mostly due to this cause. It will perhaps be of interest in this connection to note that a current meter measurement at low or medium gage height is rejected entirely if varying more than 5 per cent. from the curve.

The general practice when under high-water conditions, the current being so swift as to prevent holding the meter at any great depth below the surface, is to make observations at one foot depth (which can usually be done), and apply a coefficient obtained by study of vertical curves for the station at lower gage heights. The distance of the bridge above the water surface is a very important factor in holding the meter.

ESTIMATES OF FLOW DURING THE WINTER SEASON.

For a considerable portion of the year in New England the rivers are frozen over, and while in this condition at a given station the relation between gage height and discharge, which exists under open-water conditions, no longer prevails. The ice cover forms usually during the period from the middle of November to the first of January, depending upon latitude and conditions; while the ice remains in many streams as late as the first of April and some times up to the first of May. There is, consequently, a considerable portion of the year when different methods of estimate must be used from the ordinary. In winter, too, the measurement of precipitation is more difficult and available data less accurate than for the summer season. In fact, there

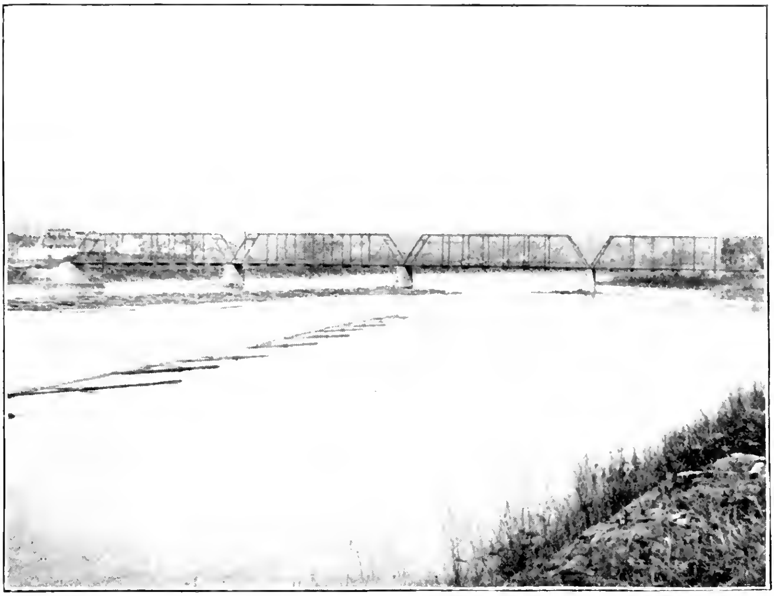


Fig. 1. Aroostook River at Fort Fairfield, Me. Gaging Station—Interference with Logs.

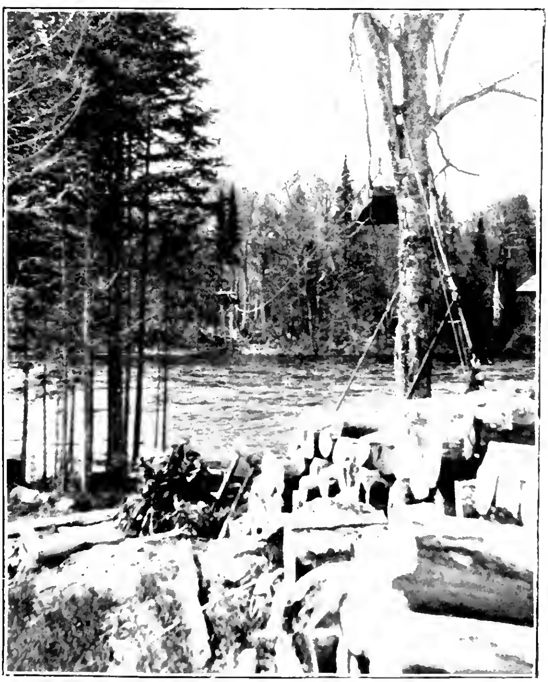


Fig. 2. Moose River at Rockwood, Me. Cable Station.

is not even an approximate relation between snowfall and stream flow, so that no estimate of stream flow can be made from the precipitation in winter. In the northern New England states especially, the minimum flow for the year may occur during the winter season, as the inflow of the streams is generally from springs, ground water, and lake storage. A water-power plant is often taxed at its highest capacity during the winter time, as the days are much shorter and more power is consumed in lighting. Consequently, it is often of the utmost importance to know something definite of winter flow under such conditions. There are numerous difficulties met with in making winter estimates of flow by any of the ordinary methods, and for this reason the data relative to winter flow of streams are very meager compared with those for the rest of the year.

CURRENT METER STATIONS IN WINTER.

The condition of New England streams during the winter season may perhaps be classified as follows:

(1.) Streams which do not freeze over, or perhaps only for short times. This may be due to several causes. The most common case is that of a stream near the outlet of a lake and where the velocity is considerable. Frequently a river will be open for some little distance below a dam, if quick water exists.

(2.) Streams which freeze over smoothly and permanently for the winter, and where the range of rise and fall is small.

(3.) Streams where ice conditions change frequently, due to breaking up of ice or the formation of anchor or needle ice.

Estimates of flow for the first two classes are usually practicable, although the cost may be two or three times that for the open season.

METHODS USED.

During the winter of 1903–4, out of thirty current meter stations maintained in New England, a record of gage heights to water surface in a hole cut in the ice, and the data relating to the thickness of the ice, was kept at sixteen, and at one station some current meter measurements of flow under the ice were made. During the winter of 1904–5, data regarding gage heights, etc., were obtained at twenty-seven out of forty current meter stations, and

current meter measurements made at three stations. The effort has been to procure sufficient data as regards gage heights, etc., to be able to compute the flow during these winter months later on when perhaps meter measurements will have been made in sufficient number under ice conditions for a winter rating curve, or perhaps a relation established between summer and winter flow for a given station. This feature of estimating stream flow must be regarded as largely experimental up to the present time.

The manner of using the current meter under winter conditions has been to cut holes in the ice, perhaps two feet long and one foot wide, at intervals of 10 or 20 feet or less, depending on the total width of the river. Velocity observations have been practically all made by the multiple point method, and vertical velocity curves obtained, as it is desired to procure as much information as possible on the form of velocity curves under ice conditions, and to furnish means for study to determine other methods which will be quicker as regards field work. The current meter has to be kept in the water continuously or it will become coated with ice and impossible to use. In some cases it has been found that considerable pulsations occur of the water through holes in the ice. At Richmond, Vt., on Winooski River, holes being five feet apart, rapid pulsations of a half foot or less occurred and caused considerable trouble at first. This was stopped by cutting between a few of the holes and making a continuous channel.

USE OF WATER-POWER PLANTS FOR ESTIMATES IN WINTER.

The difficulties under such conditions are that the dam frequently becomes coated with ice and so changed in the cross section and in conditions as to make the flow over it very difficult to ascertain. Where the flow is largely through the turbines, less trouble occurs, and fairly good estimates of flow may be obtained in this way.

OTHER WORK OF THE HYDROGRAPHIC BRANCH IN NEW ENGLAND.

This branch of the Geological Survey is not limited to the estimation of stream flow, but is intended to cover the broad subject of hydrography, and, in general, to aid in the study and solution

FIG. 1. MOOSE RIVER AT ROCKWOOD, ME. GAGE USED WITH CABLE STATION.

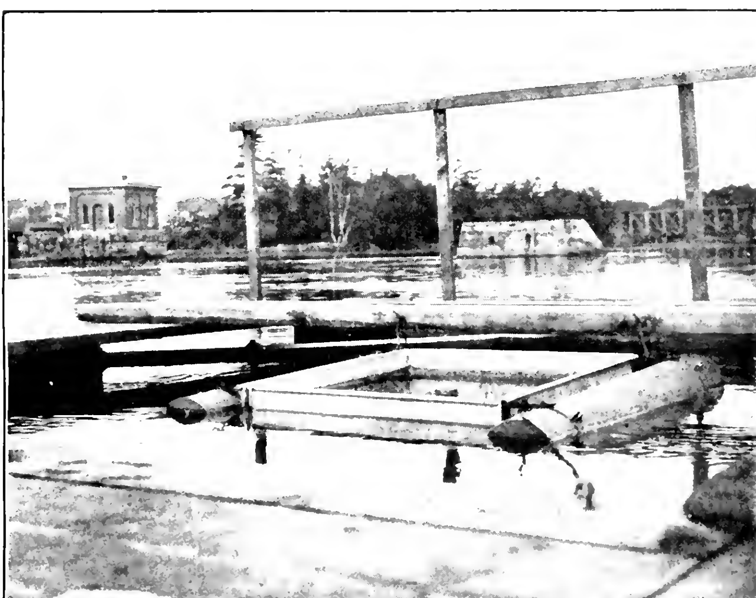


FIG. 2. EVAPORATION PAN AND FLOATS IN ANDROSCOGGIN RIVER AT LEWISTON, ME.

of problems connected with river flow and with the lakes of New England. Thus, in the state of Maine, surveys of some of the important water-power streams have been made for the purpose of obtaining plans and profiles. In 1904, the Kennebec and Penobscot rivers were covered in this way for a considerable part of their length. During the present season the survey of the Androscoggin River has been begun, and further work done upon the Kennebec and Penobscot rivers.

Another feature of Maine hydrography that is now being studied by the aid of surveys is that of storage in the Kennebec River headwaters. This stream is naturally endowed with a great series of lakes which are admirably suited for storage purposes, the largest of these being Moosehead Lake. While some regulation has been made of the outflow of these lakes, there still remains considerable to be done before the minimum flow of the Kennebec River is brought to the desirable pitch.

The study of evaporation is being carried on, and during the present summer stations to measure this and to procure the attendant meteorological data are being maintained at Lewiston on the Androscoggin River, at Millinocket on Ferguson Pond, and at Wallagrass on Soldier Pond.

It is intended to gradually accumulate data on the water powers of New England and regarding sites for water power as yet unused, and to have this information generally available for engineers and other parties interested, either in shape of reports or on file at the Washington and district offices.

Lists are appended of the Water Supply Papers and Reports of the Geological Survey that have been published up to the present time: (1) Upon hydrographic methods and investigations of general interest; (2) those containing data on the flow of streams, water powers, etc., of New England.

UNITED STATES GEOLOGICAL PUBLICATIONS RELATING TO GENERAL HYDROGRAPHIC INVESTIGATIONS.

Nineteenth Annual Report, Part IV, 1897, pp. 17–31. "Methods of Measurement."

Twentieth Annual Report, Part IV, 1898, pp. 20–22. "Methods of Measurement."

Twenty-first Annual Report, Part IV, 1899, pp. 28–41. "Methods of Investigation; also, Difficulties in Measuring Flow over Dams."

Water Supply Paper 35, 1899, pp. 11–25. "General Discussion of Methods."

Water Supply Paper 47, 1900, pp. 10–15. "Methods of Using Stream Gagings for the Computation of Water Power."

Twenty-second Annual Report, Part IV, 1900, pp. 49–50. "Methods of Investigation."

Water Supply Paper 56, 1901. "Methods of Stream Measurement."

Water Supply Paper 64, 1902. "Accuracy of Stream Measurement."

Water Supply Paper 76, 1903. "Observations on Flow of Rivers in Vicinity of New York City.

Water Supply Paper 80, 1903. "Relation of Rainfall to Run-off."

Water Supply Paper 94, 1904. "Hydrographic Manual."

Water Supply Paper 95, 1904. "Accuracy of Stream Measurement." (2d ed.)

UNITED STATES GEOLOGICAL SURVEY PUBLICATIONS RELATING TO HYDROGRAPHY IN NEW ENGLAND.

Nineteenth Annual Report, Part IV, 1897, pp. 34–117.

Twentieth Annual Report, Part IV, 1898, pp. 45–47; 64–78.

Water Supply Paper 27, 1898, pp. 9–16.

Twenty-first Annual Report, Part IV, 1899, pp. 50–63.

Water Supply Paper 35, 1899, pp. 25–44.

Twenty-second Annual Report, Part IV, 1900, pp. 56–81.

Water Supply Paper 47, 1900, pp. 29–36.

Water Supply Paper 65, 1901, pp. 13–42.

Water Supply Paper 69, 1902. "Water Powers of Maine."

Water Supply Paper 82, 1902, pp. 11–58; 77–79.

Water Supply Paper 97, 1903, pp. 14–103; 338–355.

Water Supply Paper 124, 1904. Entire.

Water Supply Paper 129, 1904, pp. 139–143.

THE WATER SUPPLIES OF THE NEW YORK METROPOLITAN DISTRICT WITH SPECIAL REFERENCE TO THEIR PURIFICATION.

BY GEORGE C. WHIPPLE, CONSULTING ENGINEER,
NEW YORK CITY.

[*Read September 15, 1905.*]

Mr. President, and Fellow Members of the New England Water Works Association. — I don't know how many times you have been told during the last few days that New York is a great city. You heard it from those who gave the addresses of welcome, you read it in the descriptive pamphlet prepared by the committee, and you have had a chance to see something of it for yourselves; and now, lest I be thought lacking in local patriotism, I want to say it again. Yet, after all you have seen and heard, I doubt if even now you have come to fully recognize the bigness of New York. When you went to Coney Island by steamer yesterday you thought, no doubt, that you were leaving the city behind you; yet the Statue of Liberty, which stands far out in the harbor, is really the center of a semicircle which bounds the city limits. From this statue it is 18 miles to the most northerly point of the borough of the Bronx, 18 miles to the most southerly point of the borough of Richmond, and 18 miles to the most easterly boundary of the borough of Queens. The western boundary of the city, formed by the Hudson River, the harbor, and the narrow channels west of Staten Island, is almost a straight line. Of the 500 square miles included in this semicircle, 327 square miles represent the land area of Greater New York. (See Fig. 1.)

NEW YORK METROPOLITAN DISTRICT.

If our eighteen-mile semicircle be extended over New Jersey it will include something over 400 square miles of land surface and about 45 cities and towns in that state. Some of these cities are large and important, as, for instance, Jersey City, Newark, Elizabeth, Hoboken, Weehawken, etc., while the Oranges, Montclair, Engle-

wood, etc., are well-known suburban communities. The New Jersey people are, to be sure, in a different state from New York, yet their relations with the greater city are very close, and when the ferries which now cross the Hudson River shall be supplemented by the tunnels under construction this relation will become

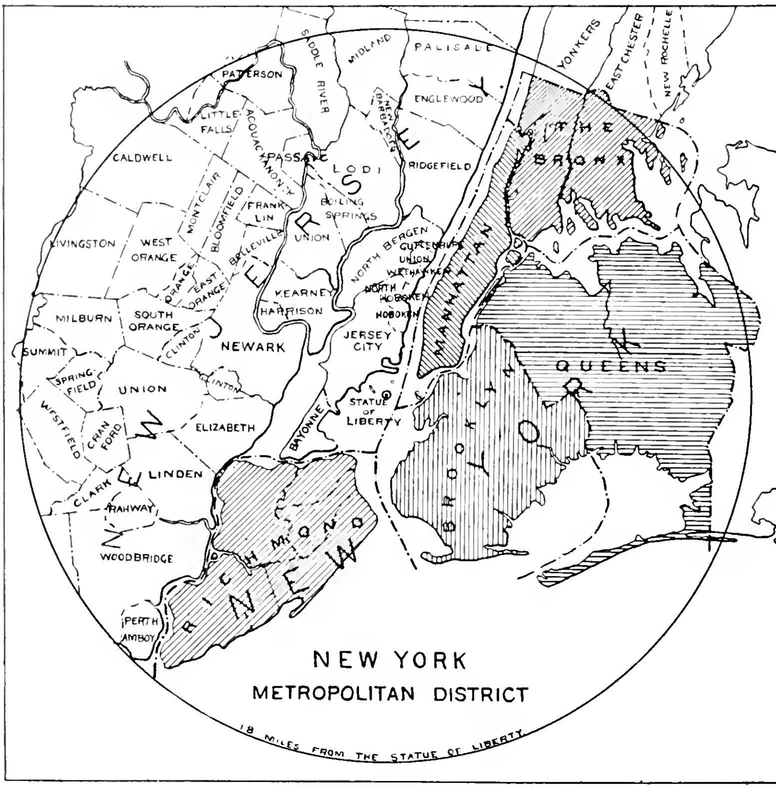


FIG. 1. DIAGRAM SHOWING THE CITIES AND TOWNS INCLUDED IN THE NEW YORK METROPOLITAN DISTRICT.

closer. Thus, while these New Jersey communities are never likely to become a political entity with New York, the region included within the eighteen-mile circle may be not inappropriately termed the Metropolitan District, as it has one vital center and many interests in common.

Outside of this circle on the north side there is a large suburban district which is just as closely connected with the city as the New Jersey townships above mentioned. To include them our radius must be extended to 30 miles. This wider circle brings us to the Connecticut line. Outside of it lie New England and the rest of the world.

The present population of Greater New York is something over four millions. There are at least one million people within the eighteen-mile limit in New Jersey, and there are half a million more people within the north suburban zone of New York. Thus, taking the New York Metropolitan District as a whole, there are at the present time more than five and a half million people who live within thirty miles of the Statue of Liberty. But even these figures do not tell the whole story. New York City is growing at the rate of 27 per cent. every ten years, and the suburban districts around New York are increasing at the rate of more than 30 per cent. In twenty years from now New York City will have a population of six millions, and in the entire Metropolitan District there will be more than eight million people.

To provide this great group of communities with pure and wholesome water, — enough for fire purposes, enough for all domestic, industrial, and public uses, and enough to gratify the American instinct of using a pint and wasting a quart, — is without exception the most gigantic municipal water-works problem of the world.

WATER CONSUMPTION.

New York City is now using upwards of 450 million gallons of water a day, and the entire Metropolitan District is using nearly 600 million gallons, or about 110 gallons per capita. While this figure is higher, perhaps, than it should be, and represents a lavish use and waste of water, yet, judging from common experience, there is reason to believe that in spite of all efforts to stop leakage in the mains, and in spite of all efforts to restrict waste even by the severe method of metering (which, I believe, should and will be ultimately adopted), this per capita consumption is destined to increase instead of diminish during the next quarter of a century. In all probability the district, as a whole, will be using 125 gallons per capita in 1925, while the main parts of New York City may

be using upwards of 150 gallons. If we allow 150 gallons per capita for Manhattan and the Bronx, 125 gallons for Brooklyn and Queens, 100 gallons for Richmond and the rest of the Metropolitan district, then in twenty years from now the total quantity of water needed each day will be more than one billion gallons, or enough to cover a square mile to a depth of 5 feet.

WATER RESOURCES.

Fortunately, the water resources which lie within a reasonable distance of the city are ample to meet this enormous demand if only they are properly developed: in fact, New York is singularly fortunate in this regard. The entire Metropolitan region is situated at a comparatively low elevation; in only a few places does the land lie higher than 200 feet above sea level, and a considerable proportion of the most thickly settled parts is lower than 100 feet. The district is surrounded on the north and northwest by an upland region, where the rainfall is ample, where the facilities for water storage are good, and where the natural quality of the water is excellent. Within 100 miles of the district there are large areas where the land has an elevation higher than 500 feet, and within a radius of 200 miles there are areas where the elevation is even higher. The opportunities for upland gravity supplies are therefore excellent. This highland region lies partly in New York, partly in New Jersey, and partly in Connecticut. Not all of these tracts, however, are available or capable of economical development, and in some cases the danger of interstate complications prevents the carrying out of what would be otherwise advantageous projects. But even after barring out those supplies which are open to legal objections, it remains true that the State of New York can furnish ample water resources for her greatest city, while New Jersey is able to take care of herself in the way of supplying those of her cities which lie within the Metropolitan District.

Besides these upland sources there are other sources of water supply available to the district. On Long Island and Staten Island there are portions of the Atlantic coastal plane, covering several hundred square miles, where vast stretches of sand offer unique facilities for the collection and utilization of ground water.

From these sources there might be supplied, if necessary, all the water needed for the boroughs of Brooklyn and Queens. At present some of these sources are barred out by legal restrictions (*i. e.*, Suffolk County on Long Island), and on account of the necessity of pumping the Long Island water it may be found cheaper, perhaps, to obtain a part of the supply from upland sources rather than to extend the aqueduct indefinitely on Long Island. Nevertheless, the water is there and may be utilized if it ever becomes necessary.

In addition to these sources there is the Hudson River, which passes through the heart of the district, draining an area of more than 12 000 square miles. By filtration at some point above the limit of the run of salt water, it would be possible to obtain a very large quantity of satisfactory water. In the distant future it may become necessary to utilize water from this source.

PRESENT SOURCES OF SUPPLY.

There are at present more than 100 distinct sources of water for the New York Metropolitan District. They include almost every conceivable type of supply, — lakes, large impounding reservoirs, rivers with small storage and rivers with no storage at all, river waters filtered, dug wells, shadow wells, infiltration galleries, ground waters filtered, and surface and ground waters mixed. About half of these sources lie inside the limits of the Metropolitan District, but these local supplies are small and scattered and together do not furnish more than about fifty million gallons a day out of the six hundred millions used by the entire district.

If we classify the supplies according to their sources we find that there are 20 lakes and reservoirs where the storage is large, 17 small storage reservoirs, 11 filtered river waters, 61 ground waters, and 1 ground water filtered. Of the entire supply about 15 per cent. is ground water, 10 per cent. is surface water filtered, and 75 per cent. is surface water unfiltered.

All of the water furnished to Manhattan and most of the water furnished to Brooklyn and the Bronx is supplied by the city, but in Queens and in Richmond the service is quite largely controlled by private companies. In New Jersey, also, private water com-

panies are strongly intrenched, although Newark and some of the other cities control their own supplies.

WATER OBTAINED WITHIN THE DISTRICT LIMITS.

About fifty million gallons of water a day are derived from local sources which are situated inside of the district limits. This is particularly true of the boroughs of Queens and Richmond, where ground water is utilized by means of driven wells scattered over the area. Some of the suburban sections of Brooklyn are likewise supplied with ground water. In Brooklyn some of the ground water is pumped into the distribution pipes and mixed with the Ridgewood water, which forms the main supply of the city; but in Flatbush, the most attractive of Brooklyn's suburbs, the supply is entirely distinct and the excellent quality of the supply is considered by real estate dealers as a valuable asset. Certain portions of the Bronx receive water from local driven wells, and the residential section lying to the north of the city, including Yonkers, Mount Vernon, New Rochelle, Mamaroneck, Port Chester, White Plains, Ardsley, Tarrytown, etc., also receive water from near-by sources. In New Jersey this is true of Elizabeth, Perth Amboy, Summit, and some of the smaller places.

WATER FROM OUTSIDE SOURCES.

By far the greater portion of the Metropolitan District is supplied with water from sources which lie at some distance from the city. (See Fig. 2.) The most important outside sources are seven in number; they are:

1. The Croton River, which supplies all of Manhattan and a part of the Bronx.

2. The Bronx and Byram rivers, which also supply the Bronx.

3. The Ridgewood system of streams and driven wells on Long Island, which forms the greater part of the supply of Brooklyn.

4. The Hackensack River which, from its pumping station at New Milford, supplies the cities of Hoboken, Weehawken, and more than thirty towns and villages.

5. The Pequannock River, which supplies the city of Newark.

6. The Rockaway River, which forms the present supply of Jersey City.

7. The Passaic River, which, from a pumping station at Little Falls, supplies Paterson, Passaic, Montclair, Bayonne, Kearney, Harrison, and other smaller places.

These supplies, taken together, furnish in round numbers about 550 million gallons of water a day.

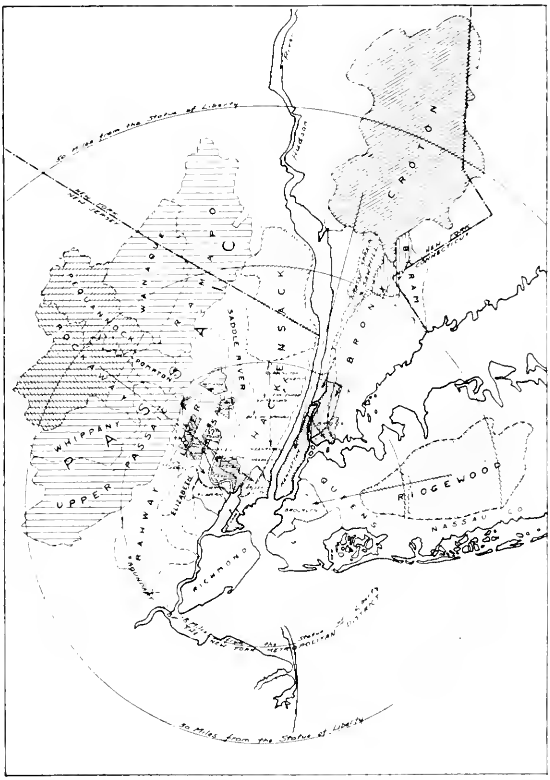


FIG. 2. DIAGRAM SHOWING THE PRINCIPAL DRAINAGE AREAS WHICH FURNISH WATER TO THE NEW YORK METROPOLITAN DISTRICT.

Great as the present sources of water supply appear to be, yet in New York City the consumption has already caught up with the safe yield of the watersheds, and an increased supply is urgently needed. It is unnecessary at this time to describe the various investigations which have been made in connection with

this subject. They have been fully set forth in official reports. It is sufficient to state that steps are now being taken to provide an additional supply sufficient to furnish all the water that New York will need for a generation. The source of supply has been selected; authority for the new work has been obtained; executives have been chosen, and the machinery is being put in motion to construct the gigantic works necessary for the storage of the water, for its sanitary protection, and for its delivery to the city. The source selected for immediate development is the Esopus River, a stream which flows into the Hudson River from the west at a point about 100 miles from the city; it has a drainage area of 255 square miles on the southern slopes of the Catskill Mountains. Here the facilities for storage are good and the quality of the water excellent, better, in many ways, than the present Croton water. It is a supply of which Father Knickerbocker will be proud. After the Esopus, the Rondout, the Catskill, the Schoharie and other neighboring watersheds can be developed.

Projects for the utilization of ground water on Long Island have been considered also, but no far-reaching method of development has yet been decided upon. One new feature of the Brooklyn supply, however, is worthy of mention, namely, the infiltration galleries now being constructed. The borough now has a large number of small driven-well stations on its watershed, from each of which a supply of from one to five million gallons per day is obtained. To reduce the cost of maintenance and increase the supply of water, it was decided to try a tile pipe, laid with open joints, surrounded by gravel, the bottom of the pipe being laid about five feet below mean high tide at the central well and extending, in an easterly and westerly direction, at right angles to the line of underground flow, for a distance of about one and one-quarter miles each way from the central well. The invert of the pipe at the end of the line is about two feet below mean high tide. The pipe is laid with open joints, surrounded by gravel, and it is expected to utilize all the water flowing through the pervious sand strata on the south side of Long Island. The first of these galleries has been located near Wantagh, Long Island. It consists of a 36-inch vitrified pipe at the pump well, gradually reducing to a 20-inch pipe at the end

of the line. Where the gallery passes through the village of Wantagh cast-iron pipe is used to prevent any possible contamination and also to avoid drawing too heavily on the ground water through the village. It is expected to establish six or seven additional galleries, practically paralleling the entire conduit line from Massapequa to the Spring Creek Station, leaving out, however, the territory in the immediate vicinity of the villages of Rockville Center and Freeport.

No projects of any magnitude for the increase of the water supply in New Jersey from outside the limits of the watersheds already mentioned are being considered, but should more water be needed there are numerous watersheds to the north and northwest of the present areas which might be drawn upon.

QUALITY OF THE PRESENT SOURCES OF SUPPLY.

So numerous are the sources that it is difficult to make any general statement in regard to the quality of the water furnished to the Metropolitan District which will adequately express the facts. It may be said, however, that from the standpoint of public health, the water supplies of New York compare very favorably with those of other cities of the country. As a rule, the surface waters are neither extremely high colored nor very turbid, except for short intervals after rains. Like most surface supplies, the water becomes unpleasantly odoriferous during the summer months on account of the growth of microscopic organisms in the storage reservoirs. The average growth of these organisms is, perhaps, somewhat greater here than in the vicinity of Boston; which may be due, in part, at least, to the fact that the stripping of reservoir sites is not as generally practiced in this vicinity as has been the case with the reservoirs of the Boston Metropolitan District. The Croton water often smells bad during the summer, and contains more or less sediment which makes it unsightly. All of the Croton reservoirs were filled without treatment of the sites, and the result has been the establishment of regular growths of algæ of various kinds in all of them, but especially in Croton Lake itself. In Brooklyn the Ridgewood supply is, in general, somewhat less unattractive, but a few years ago its condition was quite as bad as that of the Croton water. What is

true of the Croton and Ridgewood supplies is true in a general way of the other surface supplies in this vicinity which are used without filtration.

The ground waters near New York are generally of good quality, although some of them are hard, and a few contain excessive amounts of iron, while some, which are located near the seacoast, contain large amounts of salt.

From a sanitary standpoint we are in the habit of judging waters by the typhoid fever death-rates of the cities supplied by them. Considering the New York Metropolitan supplies from this point of view, it may be stated that the typhoid fever death-rates in this region are generally low. The average typhoid fever death-rate in New York City, taken as a whole, is about 20 per 100 000, although it varies in different boroughs and is slightly different for different years. As a rule, the annual typhoid death-rates are somewhat below 20 in Manhattan and somewhat above 20 in Brooklyn; in the Bronx they seldom exceed 15; in Queens they are between 15 and 20; in Richmond about 20; in New Jersey the typhoid death-rates have a similar range. In some places they are as low as 10, while in a few cases they are as high as 30. Without going into the figures in detail it may be said that the average death-rate from typhoid fever in those cities and boroughs of the Metropolitan District which are supplied with ground water or filtered water is about 15 per 100 000, while in those boroughs supplied with surface sources not filtered the average death-rate is nearer 20. This fact is not due entirely to the quality of the water, but there is no doubt that the water has much to do with it.

In connection with this use of typhoid fever death-rates as an index of the quality of water, I should like to express my opinion that the time is coming when we shall look not only to the death-rate from typhoid fever but to some of the other health statistics. It is a well-known fact that typhoid fever is by no means the only disease which can be transmitted by water. There is good reason to believe that many of the common intestinal disorders, especially those which affect young children, are caused by bacteria transmitted through the public water supply. Experimental evidence upon this point is not very strong as yet, but in some cases statis-

ties have been obtained which show it to be a fact. It is not certain that the bacteria which cause these troubles are due to actual pollution, and it is quite possible that some of the more common forms of bacteria found in surface waters may be responsible for part of the trouble. Children consume large quantities of milk, and frequently the milk is diluted with water. Therefore, if the water contains objectionable bacteria they are likely to develop in the milk, and their effect, therefore, may be multiplied a thousandfold. When a city changes its water supply from a contaminated water to a filtered water there is an immediate reduction in the deaths from diarrheal diseases, and of children under five years of age. This is often greater than the reduction in the amount of typhoid fever.

As an illustration of this I should like to call attention to some statistics recently compiled from the neighboring cities of Albany and Troy.

EFFECT OF FILTRATION ON DEATH-RATES AT ALBANY AND TROY, N. Y.
(DEATH RATES PER 100 000.)

	ALBANY.			TROY.		
	1894–98. (Before filtration.)	1900–04. (After filtration.)	Difference.	1894–98.	1900–04.	Difference.
Typhoid fever	104	26	78	57	57	0
Diarrheal diseases	125	53	72	116	102	14
Children under 5 years	606	309	297	531	435	96
Total deaths	2 246	1 868	378	2 157	2 028	129

PERCENTAGE REDUCTION OF DEATH-RATES.

	Albany	Troy
Typhoid fever	75	0
Diarrheal diseases	57	12
Children under 5 years	49	18
Total deaths	17	6

Filtered water was introduced into Albany in 1899. The water supply of Troy has remained practically unchanged.

The figures show the average death-rates for five years before and after the introduction of filtered water at Albany, and the

corresponding death-rates for the city of Troy, where the water supply was not materially changed. It will be noticed that whereas the reduction in typhoid fever amounted to 78 deaths per 100 000, the reduction in diarrheal diseases amounted to 72 deaths and the reduction in deaths of children under five years of age was 297 per 100 000 in Albany. In Troy the reduction in the deaths from diarrheal diseases and of children under five years of age was much smaller. These cities are similarly situated, and their sanitary conditions differ chiefly in their water supplies. It is fair to assume, therefore, that the improvement in the health of the city of Albany was due to the filter which was installed in 1899.

Another table illustrating this fact was presented by Allen Hazen at the International Engineering Congress recently held in St. Louis. It represents results obtained from many American cities and shows that there is a reduction in the total death-rate due to the introduction of filtered water which is much greater than that accounted for by the decrease in typhoid fever. Either the cause of other diseases must have been reduced by the use of filtered water or else the general tone of the public health was improved by the increased purity of the water supply.

	Per 100 000
Reduction in total death-rate in five cities with the introduction of a pure water supply	440
Normal reduction due to general improved sanitary conditions, computed from average of cities similarly situated but with no radical change in water supply	137
Difference, being decrease in death-rate attributable to change in water supply	303
Of this, the reduction in deaths from typhoid fever was	71
Leaving decrease in deaths from other causes attributable to change in water supply	232

In New York, and especially in Brooklyn, diarrheal diseases akin to typhoid fever are sometimes quite prevalent, and while there is no direct proof as yet, there is reason to believe that these are in some way associated with the quality of the water. The death-rate of children under five years of age is also somewhat high in our city. There are, no doubt, many reasons for this, but among them the quality of the water supply is certainly not the least.

While the water supplies of New York are reasonably free from pollution and while the supervision is fully as elaborate as exists in most American cities, yet, with so large an area of watershed to be covered, it is manifestly impossible to completely eliminate all contamination, and as time goes on the effect of this will materially increase.

Public opinion is beginning to crystallize in regard to the matter, and the need of filtering the main supplies of New York and Brooklyn is gradually being appreciated. The advantages of filtration in this city are unmistakable and it is to be hoped that when the New England Water Works Association again meets here we shall not be obliged to apologize in any way for the quality of the water which runs from our service taps, but that we can present you with a glass of water drawn from our city mains equal in quality to that of any city in the country. Years ago the Croton water had an enviable reputation among American cities. Its supremacy has been lost not through its own deterioration, but because of the improvement in the supplies of other cities. There are sound sanitary and economic arguments in favor of filtration, but, even putting these aside, it is to be hoped that for the sake of civic pride alone this supremacy may be regained. Filtration of the Croton water, coupled with the magnificent new supply which is to be derived from the Catskill Mountains, will give our great American metropolis almost the best large water supply in the world.

FILTRATION IN THE VICINITY OF NEW YORK.

Notwithstanding the fact that the water of New York City is not filtered at the present time, there is probably no better place in the country to study the development of water filtration than in the immediate vicinity of this city. Within a radius of seventy-five miles can be found the first slow sand filter constructed in this country, and the first mechanical filter ever put into operation for a municipal plant. There can be found, also, types of the most modern slow sand filters, and mechanical filters which embody many of the latest ideas. Between the earliest and simplest types of filters and the latest and more modern types, many other kinds may be found which represent different stages

in development and which embody differences in design in order to adapt them to various kinds of waters.

I will now refer briefly to some of the various filters which are to be found in this locality. There will not be time to consider any of them in great detail, but the descriptions will serve to give an idea of what is going on around New York in the way of filtration.

POUGHKEEPSIE, N. Y.

The filters at Poughkeepsie were the first sand filters built in the United States. They were designed by James P. Kirkwood in 1872. The old filters are still in use, but in 1896 they were enlarged to provide for the increased consumption in the city. The filters as originally constructed were not covered, but during the past year covers have been added in order to get rid of the trouble which has been experienced in removing ice from the sand beds during the winter. The filters treat the water of the Hudson River, which, at Poughkeepsie, is considerably polluted, and which is frequently too turbid to be satisfactory as a drinking water.

The Poughkeepsie filters were described in a paper by the superintendent, Charles E. Fowler, which was given before this association and which may be found in Vol. XII, page 209, of the JOURNAL.

HUDSON, N. Y.

The filters at Hudson were built in 1874, two years after those at Poughkeepsie. They also were designed by James P. Kirkwood. In 1888 they were enlarged, but since that time the consumption has considerably increased, and they are not now sufficient to satisfactorily purify all the water which the city uses. The filters treat the water of the Hudson River, which is muddy and contaminated, as it is at Poughkeepsie. An account of these filters, prepared by H. K. Bishop, superintendent of public works, was given in the *Engineering News* of August 14, 1902.

There are two filters, designated the " old " and the " new." The old filter has an area of about 9 000 square feet. The new filter, which is at a somewhat higher elevation, has an area of 23 000 square feet. The old filter is practically a storage reservoir with the lower half occupied by the filtering material. The filtered water passes from it to a clear water basin adjacent to it. This

FIG. 1. OLD FILTER AT POUGHKEEPSIE, N. Y., SHOWING REMOVAL OF ICE.

FIG. 2. INTERIOR OF COVERED FILTER AT POUGHKEEPSIE (UNCOMPLETE)

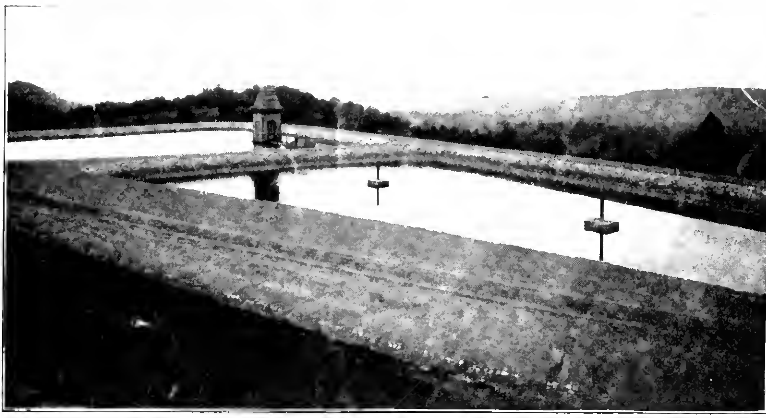


Fig. 1. Old Filter and Clear Water Reservoir at Hudson, N. Y.

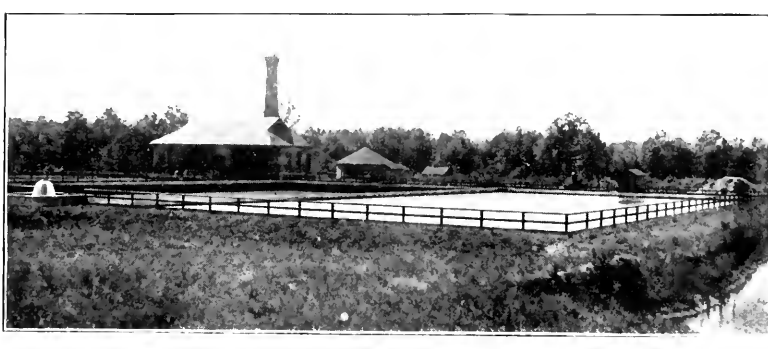


Fig. 2. Old Filter Beds at Far Rockaway, Long Island.

clear water basin also receives the filtered water from the new filter, located above it. The new filter is now in process of reconstruction.

HEMPSTEAD, L. I.

The filter at Hempstead, L. I., while of recent date, is perhaps the simplest type of filter in use in the New York Metropolitan District. It consists of an area of natural sand surrounded by earth embankments, and under-drained with a rectangular system of tile drains which discharge through a main collector into Hempstead Pond, which is adjacent to the filter and somewhat below it in elevation. From this pond the water flows by gravity into the conduit. This filter treats part of the water of Hempstead Stream, which becomes much polluted as it passes through the village of Hempstead. In its purpose and general construction it resembles the Pegan filter at Natick, Mass., which treats the water of Pegan Brook. The beds have an area of 0.6 acre each and are designed to filter between $2\frac{1}{2}$ and 3 million gallons per acre per day. The sand, which was found *in situ*, has an effective size of .27 mm. The drainage system consists of an 18-inch main pipe laid at one side of the bed, with 6-inch laterals running across the bed, 108 feet long and 10 feet apart. These pipes are surrounded by coarse gravel 18 inches wide and 16 inches deep, with 21 inches of fine gravel on the top. The high-water elevation on the filters stands about 7 feet higher than the maximum elevation of the pond into which the effluent discharges. The discharge is controlled by weirs on the effluent pipes. The total cost of the beds was $11 000. This low cost was due to the simple form of construction and to favorable conditions at the site.

Not only are these filters simple in construction but they are also operated in a simple manner. The water flows through them with almost no regulation and the attention required is therefore very little. When the surface of the filter becomes clogged the sand is not removed in the usual way by scraping, but, instead, the sediment is washed off by means of flowing water applied to the surface. For this purpose planks are set on edge so as to divide the filter longitudinally into channels 15 and 20 feet wide. Raw water from the adjacent filter is then allowed to flow slowly down these channels, the surface of the sand being raked meanwhile in

order to loosen the sediment so that it will be carried away with the flowing water. The rate of flow is so adjusted that practically no sand is lost, and the result is said to be practically as good, so far as it affects the efficiency of the filters, as the more expensive method of scraping the sand and washing it. This method of scraping is a novel one in this country although it has been used to some extent abroad. While it may be applicable in this case, it is doubtful if it would work satisfactorily with waters which contain sediment composed chiefly of clay.

The cost of operation, including interest charges and all materials and labor, is estimated by the water department as $1.04 per million gallons. Of this about two thirds represents interest on the investment. The bacterial efficiency of the filter is excellent. The number of bacteria in the raw water varies from 200 or 300 up to 8 000, but it is seldom that the number of bacteria in the filtered water exceeds 50.*

FOREST STREAM, L. I.

The filters at Forest Stream are somewhat similar to those at Hempstead, having no water-tight floor and having the side walls constructed of earth embankments. They are similar also in having no elaborate system of regulating the flow. They differ, however, from the Hempstead filters in that the filter bed is not a natural one but is made of washed sand. As the filters are at a somewhat low level compared with the ground water table and as there is no filter floor, the drains collect some ground water, but thus far no trouble has been experienced from this source. The beds were constructed by excavating to the desired grade and placing 6 inches of coarse gravel and 2 inches of fine gravel over the bed. Below the laterals the bottom was excavated so as to have drains 18 inches wide and 8 inches deep in which coarse gravel was placed. Coarse and fine gravel was also placed above the laterals. The filter beds have a combined area of 2.5 acres, and are three feet deep. The sand itself has an effective size of .28 to .30 mm. Most of it was obtained by washing material taken from the excavation.

*These and other data regarding the Brooklyn filters were kindly furnished by Mr. I. M. de Varona, chief engineer, department of water supply, gas and electricity.

Fig. 1. Sand Filter at Hempstead, Long Island.

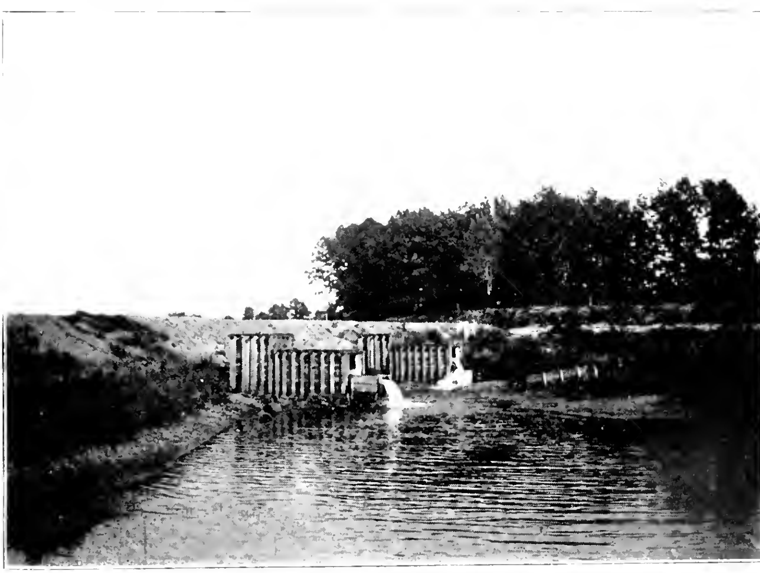


Fig. 2. Sand Filter at Hempstead, Long Island, showing Effluent discharging into Hempstead Pond.

The operation of the beds is controlled by a pump. At the present time the beds are cleaned by scraping, but it is intended to make arrangements by which they can be washed as in the case of the Hempstead filters. The efficiency is said to be good. The number of bacteria in the raw water varies from 400 to about 8 000, while the number of bacteria in the effluent is ordinarily below 50 and seldom more than 200. The quantity of water filtered varies from 2 to 3½ million gallons per acre per day. The original cost of this plant was $40 000.

FAR ROCKAWAY, L. I.

Far Rockaway, an important suburban community in the borough of Queens, and also a somewhat noted summer resort, is supplied with water from driven wells, which is filtered in order to remove the iron it naturally contains. These filters were constructed in 1896. The plans were drawn by Allen Hazen, consulting engineer. The original plant consisted of two sand beds, which had a combined area of 40 000 square feet. The sand used was natural sand, found in the immediate locality. Before the water passes over the beds it receives a certain amount of aëration by spilling over the edge of an upright pipe. This aëration serves to remove the free carbonic acid from the water and to oxidize the iron which is present so that it really precipitates in the form of ferric oxide. This precipitation occurs over the sand bed and there is formed on the top of the sand a thick brown layer, while the water leaving the filter is almost free from iron and perfectly satisfactory for domestic use. As the filters are open, filamentous algæ develop in great numbers on the top of the sand, and the iron rust becomes mixed in with them to such an extent that when the beds are cleaned there is a tenacious scum on the sand which may be rolled up like a carpet. This materially increases the ease with which the beds are cleaned. A full description of this filter plant as first constructed may be found in the *Engineering News*, April 12, 1900. Recently the plant has been enlarged under the direction of the chief engineer, Mr. Charles R. Bettes.

NYACK, N. Y.

The village of Nyack is situated on the west bank of the Hudson

River, 28 miles from New York City. Its water suppply is taken from one of the tributaries of the Hackensack River. Slow sand filtration was introduced in 1899. The general plans were drawn by Allen Hazen, consulting engineer, in 1897, but were afterwards modified somewhat, by L. L. Tribus, to adapt them to local conditions.

There are two beds, 160 feet by 120 feet. The sand is 3 feet thick, resting on 1 foot of gravel. The present consumption is 650 000 to 700 000 gallons per day.

This filter was described in the *Engineering Record*, April 28, 1900.

YONKERS, N. Y.

The filter plant at Yonkers was constructed in 1903 from plans and specifications also drawn by Allen Hazen, consulting engineer. The plant was designed to fit special conditions, and for this reason it differs somewhat from the ordinary layout. It is a slow sand filter with two beds of about one-half acre each, and a clear water reservoir which holds about 200 000 gallons. The filters are not covered. The level of the filtering surface is below the water level of the river and water is delivered to it by gravity. From the collecting drains water flows to the clear water well and is then pumped to the distributing reservoir, the pumping station and filter being on opposite sides of the river. The filter was not covered as it was not expected to be used much during the winter. The filter is provided with the usual appurtenances for washing sand, etc. The results obtained by this filter are excellent. Description of it may be found in the *Engineering Record*, July 2, 1904.

ALBANY, N. Y.

Although Albany is at some distance from the New York Metropolitan District, yet references to filters in this vicinity would not be complete unless this plant were mentioned. It was built in 1899 by Allen Hazen, chief engineer, and its construction marked an epoch in water filtration in this country. It stands as the prototype of our American modern methods of slow sand filtration, and many filters have since been built along similar lines. A full description of the filter was given by Mr. Hazen in the Trans-

actions of the American Society of Civil Engineers for the year 1899.

The plant has given excellent satisfaction and has resulted in the improvement of the health of the city as already pointed out.

POUGHKEEPSIE STATE HOSPITAL.

A much smaller but equally interesting filter of the covered slow sand filter type is that which has recently been put in operation at the state hospital at Poughkeepsie. This filter treats the water of the Hudson River as does the city filter at Poughkeepsie. The filter consists of two beds which have a combined area of one third of an acre; its nominal daily capacity is about one million gallons.

The most interesting feature in connection with this filter is the arrangement for washing the sand. The sand court, instead of being located beside the filter beds, is placed upon the roof, which at this point is reinforced with steel. By means of a portable ejector the dirty sand scraped from the bed is forced at once to a sand washer, where it is washed by means of an upward current of water. This washer is somewhat higher than the floor of the sand court, upon which the clean sand falls and where it it is stored ready to be replaced in the sand beds when needed.

The sand washer deserves more minute description. It consists of a concrete box with five compartments. The dirty sand, mixed, of course, with the water from the ejector, enters a compartment in one corner and flows over a weir into the second compartment. At the bottom of this second compartment there are several lines of perforated brass pipe through which water is admitted. The upward velocity of the water washes the sand and carries with it the fine particles of dirt which remain in suspension while the sand itself naturally works its way across the sloping bottom of the compartment to an outlet through which it passes and falls upon the sand court. The dirty water flows over a weir on one side into the third compartment and then successively into the fourth and fifth compartments. These serve to prevent the loss of the smaller sand grains. The dirty water, of course, passes eventually to the sewer. This method of sand washing is very simple and eminently satisfactory and seems destined to

replace the more complicated method of washing by means of the sand operators of the ejector type as shown in connection with the Albany filters.

This filter was designed by Allen Hazen, consulting engineer, and a complete description of it may be found in the *Engineering Record*, January 7, 1905.

PRIVATE ESTATE ON THE HUDSON.

Anothering interesting slow sand filter is located not far from the one just mentioned and also treats the water of the Hudson River. It was designed by Messrs. Hering and Fuller. In this case, however, the situation required that the water should not only be pure and wholesome but that it should be also absolutely clear of all color and turbidity. The water is used on the country estate of one of our well-known millionaires. It is used for drinking and for bathing purposes as well. and in this case the requirements for the latter purpose were far more stringent than for the former. The accompanying photograph, Plate IV, Fig. 1, shows the bathing tank lined with white tiles, and in this tank the slightest trace of color or turbidity would be quite noticeable and would seriously offend the esthetic tastes of those who bath in this luxurious manner.

In order to obtain a water which will meet all the conditions it was necessary to use alum as a coagulant. The plant consists of a settling basin, filter beds in duplicate, and a clear water reservoir, all of which are covered. Practically the entire plant is of concrete construction. This filter is interesting as it represents an intermediate type between slow sand filtration and mechanical filtration.

SOMERVILLE, N. J.

The first mechanical filter used in this country in connection with municipal supplies was located in Somerville, N. J. It was constructed in 1885, under the old Hyatt patents. The original filters have been removed and their place has been taken by other pressure filters furnished by the New York Continental Jewell Filtration Company.

LONG BRANCH, N. J.

The water supply of Long Branch is furnished by the Tintern

FIG. 1. SWIMMING TANK ON PRIVATE ESTATE ON HUDSON RIVER, SUPPLIED WITH FILTERED WATER FROM A MODIFIED SLOW SAND FILTER.

FIG. 2. PUMPING STATION, COAGULATION BASIN, AND FILTER, PRIVATE ESTATE ON HUDSON RIVER.

Manor Water Company. The plant consists of twelve gravity filter units and three pressure filter units, each of which has a capacity of one million gallons per day. The quantity of water now filtered, however, is only seven million gallons a day. All of the filters were supplied by the New York Continental Jewell Filtration Company.

MAMARONECK AND POCANTICO.

At each of these places there are pressure filters which have a capacity of about two million gallons a day. The steel filter tanks are 25 feet long and 8 feet in diameter. In the case of Pocantico there is an 85 million gallon storage reservoir from which the water flows by gravity to a coagulation tank 20 feet in diameter and 20 feet high, after which it flows by gravity through the pressure filters to the pumping engines. These works are controlled by the New York Interurban Water Company. The water from the Mamaroneck filters supplies Mamaroneck, and those of Pocantico supply Tarrytown, North Tarrytown, and some of the villages in that section. The water supplies of Larchmont and Portchester are also filtered.

SPRINGFIELD, L. I.

Two of the streams which form a part of the Brooklyn water supply are filtered by mechanical filters before the water is pumped into the aqueduct. One of these is located at Springfield Pond and the other at Baiseley's Pond. These filters were built on plans furnished by the contractors, the specifications requiring, however, certain results as to bacterial purification, amount of coagulant, etc. This method of obtaining filters proved to be far from satisfactory. The filters first furnished failed to meet the required tests and had to be rebuilt, while the initial cost was very high. The plans originally used were modified under the direction of George W. Fuller, consulting engineer, and Robert Spurr Weston. At the present time both plants are giving excellent results, but this can be attributed more to good management than to original design. Both plants are likely to demand heavy outlays for depreciation.

The plant at Springfield has a nominal capacity of three million gallons a day. It consists of two sedimentation tanks, six filter

tanks, and one filtered water tank, all made of wood. The plant has also the usual tanks for preparing the solution of alum which is used as a coagulant. The efficiency of the plant is said to be excellent, the average bacterial removal being about 98.5 per cent., while the amount of alum used is ordinarily less than 1 grain per gallon, although at times more than 2 grains are necessary. On account of the low alkalinity of the raw water it is necessary to occasionally use soda in addition to the alum. The amount of wash water is generally between $4\frac{1}{2}$ and 6 per cent. The cost of filtration at this plant is said to be $8.91 per million gallons, of which $2.89 represents interest and sinking fund, $4.35 labor, and $1.57 materials including chemicals. No allowance, however, was made for depreciation.

A description of this filter, as well as the one at Baiseley's, may be found in the *Engineering Record*, August 26, 1905.

BAISELEY'S, L. I.

The filter plant at Baiseley's Pond, L. I., is a practical duplicate of the one at Springfield Pond, but its nominal capacity is 5 million gallons per day instead of 3 million gallons. This filter is somewhat more difficult to operate than the one at Springfield on account of the occasional presence of immense growths of algæ in the raw water. This has a very important effect on the amount of wash water.

Mr. D. D. Jackson has already described how the use of copper in Baiseley's Pond has improved the operation of this filter.

The cost of filtration at Baiseley's during the last six months of 1904 was said to be $6.46 per million gallons, which included $2.21 for interest and sinking fund, $2.53 for labor, and $1.72 for other supplies, but which did not include depreciation.

LITTLE FALLS, N. J.

The Little Falls filter is well known as the first large mechanical filter constructed on modern lines in the United States. It was built in 1899 by the East Jersey Water Company from general plans prepared by George W. Fuller, consulting engineer, and Chas. L. Parmelee, civil engineer. The nominal capacity of this plant is 32 million gallons a day. This plant is so well known and has

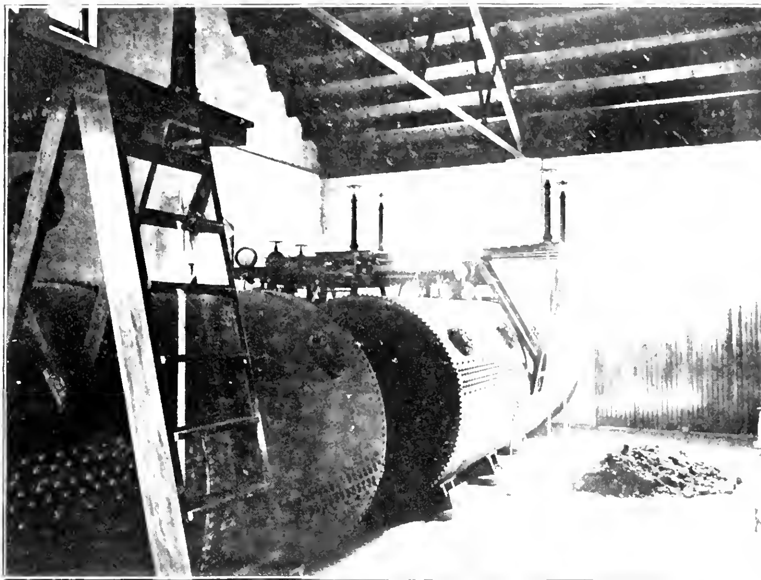


FIG. 1. MECHANICAL FILTER AT MAMARONECK, N. Y.

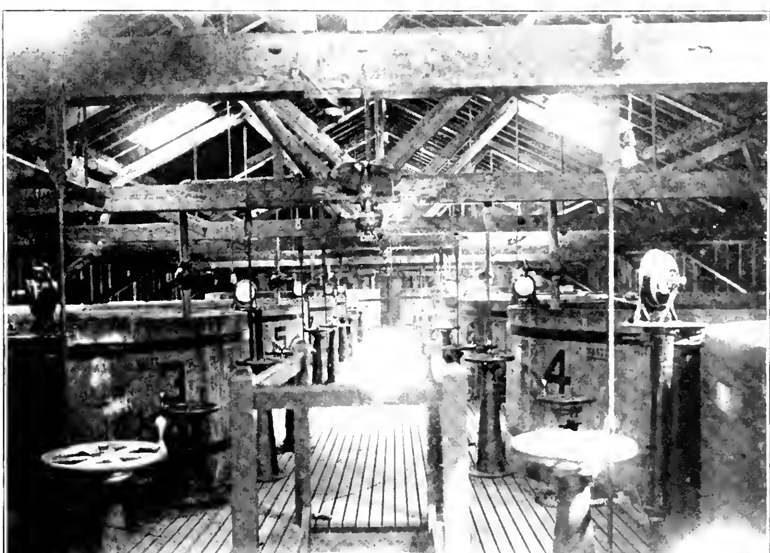


FIG. 2. MECHANICAL FILTER AT BAISELEY'S, LONG ISLAND.

been so frequently described that it is not necessary to present here a detailed description. It is sufficient to state that in operation it is giving excellent results. A very complete description of this filter, by Mr. Fuller, may be found in the Transactions of the American Society of Civil Engineers, Vol. l, page 394, 1903.

HACKENSACK FILTER.

The second largest mechanical filter in this country is now being completed at New Milford, N. J. It is being built by the Hackensack Water Company and was designed by George W. Fuller, consulting engineer. It is expected to be put into operation next month. This plant has a nominal capacity of 24 million gallons a day. Water is pumped from the conduit from the Hackensack River into a sedimentation basin, where it passes from one end to the other and flows to the filters by gravity. The filters consist of eight beds, each of which has a capacity of three million gallons a day. The alum solution is added to the water in the gatehouse before it enters the sedimentation basin.

There are several unique features in connection with this plant. Perhaps the most conspicuous is the concrete wash-water tank, located outside the filter house. This is built of reinforced concrete and has a capacity of 110 000 gallons. It is 43 feet in diameter and 10½ feet deep, and about 30 feet above the filter. Its walls are 12 inches thick. Under this tank are 8 steel cylindrical tanks for holding compressed air which is used in washing the filter. The wash-water pumps and air compressors are both driven by Pelton wheels. The tanks for mixing and applying the chemicals are located in one end of the building on the second and third stories. There is also a well-equipped laboratory for looking after the operation of the plant.

The filter beds are of unusually large size. A new style of strainer is used, constructed largely of concrete with perforated plates. On account of the large size of the beds, especial care has been taken to secure a uniform distribution of water and air. It has been the intention to eliminate patented devices from this plant as far as possible.

A complete description of this plant may be found in the *Engineering Record*, November 12, 1904.

THE USE OF COPPER SULPHATE AND METALLIC COPPER FOR THE REMOVAL OF ORGANISMS AND BACTERIA FROM DRINKING WATER.—A SYMPOSIUM.

[*September 15, 1905.*]

THE USE OF COPPER SULPHATE AS AN ALGICIDE.

BY DR. GEORGE T. MOORE, WASHINGTON, D. C.

Members of the New England Water Works Association, — I am very glad indeed to have an opportunity of meeting with you here to-day and to open this discussion, which, I hope, will be most profitable to all of us. As I understand it, I am simply to introduce the subject and furnish the basis for the more important papers which are to follow. For this reason I shall run over very briefly the history of the work in this country, and I shall hope to bring up any special points at the end of the discussion rather than at the beginning.

It is not necessary for me to refer to the effect on water of the plants known as algæ. Most members of this association know of the condition produced by these organisms, many from personal experience. My experience began some seven or eight years ago when I lived in New England and had occasion to come in personal contact, as it were, with waters affected in this way.

The first piece of scientific work which I had occasion to publish related to the life history of uroglena; the material for study I obtained at Norwood, Mass., where I had opportunity to note the condition produced in water by this plant.

After leaving Cambridge and going to New Hampshire, I was still engaged upon the problem of algal pollution, and I tried a considerable number of experiments, but because the material with which I had to work was limited, the matter ran along without much being accomplished, and after a year or two I went to Washington.

In that fall, arrangements were made with the Massachusetts State Board of Health to establish a temporary laboratory in the

State House, and Mr. Kellerman, who has been associated with me in this work, and I went to Boston and spent some two or three months there. The facilities there for procuring organisms which produce trouble in water supplies were very good indeed, and we had an opportunity to carry on experiments which, under ordinary circumstances, would have required years of preparation in order to elaborate the machinery for getting the proper samples. We were, therefore, able to obtain results which might have required very much longer had we not enjoyed the courtesies extended by the Massachusetts State Board of Health.

Our idea was, of course, to find something which would be more efficient, cheaper than any method then known or used or recommended by engineers for the destruction or prevention of the growth of algæ in water supplies, and, of course, harmless. The most profitable line of research seemed to be one involving the use of some substance which was toxic to the plants themselves, but which could be used in such minute quantities that the question of the effect upon man would be one which could be eliminated.

Of course, the work of Naegeli, Israel, and Klingman, and other early investigators in physiology, furnished us a basis. Although a large number of substances were tried, it was very soon seen that the heavy metals were going to be the things which would prove most toxic in the smallest quantities. Gold and silver naturally had to be eliminated on account of the expense, although silver, particularly in minute quantities, is very toxic to these forms. Mercury had to be left out, of course, on account of its poisonous effects upon man; and it was a very simple process of elimination to arrive at copper as the thing which warranted the most extensive experiments.

The first report which was ever presented by us on the use of any toxic substance for the destruction of algæ was a confidential report submitted to the Massachusetts State Board of Health some four years ago this winter.

The first practical use of copper sulphate as an algicide was in connection with water-cress beds in Virginia. Here, after the first crop of cress was cut, the remaining plants being very small and growing in water from a thermal spring with a temperature of about 70° the year round, the conditions were most favor-

able for the growth of algæ. Great carpets would form over the beds and smother out the young and delicate cress, causing the loss of about half the crop. The beds were perhaps two hundred yards wide and a quarter of a mile long, cut off by temporary dams for the purpose of flooding the cress in case of freezing weather.

The copper was first applied by a spray pump in the form of a strong solution. It seems ludicrous now that we should have attempted to do it in this way, but the general practice of using germicides and fungicides led us to try it. Wherever the solution came in contact with the algæ it killed them, but the copper was thrown out of solution before it penetrated the great mass of algæ and the result was not satisfactory. It, therefore, became necessary to use some other method, and applying the copper sulphate in crystal form, tying it up in a bag and dragging it back and forth through the water, was resorted to.

The solution used in this particular case was very dilute, being about one to fifty million. The conditions were extremely favorable, on account of the temperature of the water, for getting the highest toxic effect possible, and the elimination of the algæ with this dilution was complete. As a matter of fact, after the first treatment, which completely cleared the beds of the growth, it was not necessary to resort to it again for about six months, and at that time the quantity was decreased so that eventually, although copper was applied every six or eight months as a matter of precaution, it really was not at all necessary. But, as I said, this was a condition where everything was extremely favorable for the use of the copper method.

Later, other opportunities occurred for testing the method in various water supplies, and most of you must be more or less familiar with the results of the use of copper sulphate for the detruction of algæ in reservoirs. It is not necessary to refer to these cases at this time, although I hope that questions during the discussion will bring out points regarding such treatment.

Just a word in regard to the limitations of the method. Of course, the whole process is dependent upon a specific quantity of copper in solution, very minute to be sure, coming in contact with the algæ, or being in such a condition as to be absorbed by

these plants. In a closed reservoir through which there is no very great current, and where the water does not change very rapidly, the conditions are naturally very much more favorable than they would be in a supply where the water changes frequently and the current is considerable. Most important of all is the question of the selective toxicity of the organisms themselves. I refer to this because not a great while ago a very eminent authority in this country, in discussing this very question of the use of copper sulphate, made the statement that it was a well-known fact that all organisms responded in precisely the same way to all toxic substances. Certainly neither our practical experience nor theoretical knowledge regarding the use of copper in the destruction of algæ bears out that statement. As we have tried to point out from the very first, some organisms are very much more susceptible to the action of copper than others, and it is absolutely essential that we know the specific plant to be destroyed, before any definite recommendation can be made. It may mean the use of copper sulphate at the rate of one part to fifty million parts of water, it may mean using it at the rate of one part to one million, or it may mean that it cannot be used at all; because there is no question that certain organisms are so resistant to the action of copper that under ordinary circumstances it is not practicable to resort to this method.

It is conceivable that a large reservoir might be polluted with a certain alga which would naturally be so resistant to the action of copper sulphate that it would not be practicable to use it. Fortunately, however, the organisms which generally occur and which, certainly in this country, are most abundant and produce the worst odors and tastes, are the most susceptible to the action of copper. The same is true regarding the pathogenic germs, those of typhoid and cholera being among the most susceptible organisms to the toxic effect of copper. The fact that these germs do not form resistant spores makes it possible to resort to the copper method.

It is absolutely essential to have a microscopical examination in order to determine the algæ responsible for the difficulty before any definite prescription can be given. From the very first, every effort has been made to emphasize the fact that the use of copper

sulphate for the purification of a water supply, or the destruction of algæ anywhere, cannot be considered a general shotgun method. It must be used intelligently. Although there still exists a difference of opinion regarding the possible harm from copper, there can be no doubt about the fact that a man should have all the necessary information before resorting to copper, and most important of all, for the destruction of algæ, is to know the form which is to be destroyed.

The question of the presence of fish in the water is one which ought to be considered. Of course, fish vary in the same way that the algæ do, so far as their susceptibility to the action of copper is concerned. An interesting case will illustrate this, I think. A game club in northern New York had a large lake which, although originally stocked with bass, had come to contain pickerel in large quantities; consequently, when the members of the club fished in this lake for bass, they continually caught pickerel, and it was a great source of annoyance to them. The lake was polluted with *anabæna*, and it was decided to treat with copper sulphate. It was suggested to me that if some means of getting rid of the pickerel at the same time could be devised, it would be ideal. Never having attempted anything of the kind, no responsibility regarding the result could be taken, but the management was willing to experiment. We did know that bass were among the most resistant fish to copper, standing one part to one hundred thousand in the laboratory with no signs of discomfort. About the pickerel we knew little or nothing. Twice the dose which would have been used to exterminate the *anabæna* was applied, and the pickerel were taken out in such quantities as to practically eliminate them, while I believe only one bass was found dead. This is not referred to as a practice which should be encouraged by any means, but it does, I think, illustrate most beautifully the difference in the toxic effect of a given solution upon two different kinds of fish in the same reservoir, where the temperature, character of the water, and other conditions must have been absolutely the same. Nobody knows how many bass were in the lake, but certainly some thousands.

It should be borne in mind, then, that if a reservoir is stocked with fish very susceptible to copper and at the same time is pol-

luted with algæ very resistant to this metal, it is usually impossible to resort to the method, because a strength of copper necessary to eliminate the algæ would also kill the fish. Fortunately, however, this condition is more or less theoretical rather than actual, as has been shown by practical experience. Take, for instance, the Butte, Montana, case. There the reservoir was stocked with what they called mountain trout, a fish which is supposed to be very susceptible to copper, experiments showing that one part in five or six million will kill such fish. In that particular case they were fortunate in having as the polluting alga *anabæna*, which was completely destroyed by using one part of copper to eight and one-half million parts of water, without, so far as I know, injuring a single fish. The Bureau of Fisheries has been carrying on recently some experiments with copper sulphate for cleaning up breeding ponds of fish, and the results ought to throw considerable light upon the subject.

There are a number of other phases of the question which should be considered. I have not had time to refer to the temperature question, although, of course, it has been brought out in publications that the higher the temperature of the water the greater the toxicity. We have had very few opportunities for treating supplies in the winter time. In one case, however, where the application was made through the ice, the results were entirely satisfactory; but the organism destroyed was *uroglena*, a form which unquestionably is very susceptible to copper, perhaps as susceptible as any of the algæ.

The whole matter seems to resolve itself into this: The more commonly distributed algæ, such as some of the blue-greens, *uroglena*, and certain of the grass-green forms, which are usually responsible for trouble in a water supply, are likewise the most susceptible to the action of copper, and on account of this very fortunate condition of affairs the method has a practical application far beyond what it might have.

The question of the possibility of using copper to such an extent as to produce a resistant strain of algæ has been raised, and, of course, is a proper point to be considered. The fact of the matter is, however, that the whole aim and intention in using copper as an algicide is to so completely destroy the algæ as to leave nothing

from which to breed a resistant form of organisms. If the application is made at the proper time and under the proper conditions, certainly all of those organisms which are susceptible to copper will be destroyed. With spore-bearing algæ or where the organisms are buried in the mud, there cannot by any possible means be any effect from a treatment with copper sufficient to form a more resistant lot. So far as our experience goes, where copper has been used for the destruction of certain susceptible forms, conditions certainly seem to indicate that it requires a less and less amount to keep the water free from this specific organism, rather than an increasing quantity. Experience only can settle this matter, but there is no evidence at the present time to sustain this objection.

Just one other point and I will conclude. Theoretically, we find that many of the algæ respond to very definite toxic doses of copper in the laboratory; that is, working with test tubes or large aquaria, we are able to determine the amount of copper which will destroy any of the common algal forms occurring in water supplies. In actual practice it has been found that the amount of copper necessary to produce the toxic effect is not nearly so large, and this has been under conditions about which there could be no question. That is, most careful estimates of the capacity of the reservoirs being treated were made; there was not at the time the copper application was made any water passing through the reservoir, and the temperature and everything of that sort were taken into consideration. It certainly seemed that at least some of the theoretical data regarding the action of copper upon algæ, as well as its action upon pathogenic germs, which have been published, would have to be modified when used as a basis for practical work. Fortunately, however, the modification will involve a decrease rather than an increase in the amount of copper to be used.

This is not what is usually expected, and the only explanation appears to be that in the laboratory we are dealing with more resistant forms. It is very probable that algæ brought into a laboratory, grown under artificial conditions, become more resistant to any toxic substance. The reasons for this cannot be gone into in detail, but we know that a great many of the weaker forms

die out in the laboratory, and in almost every case it seems probable that the forms upon which the experiments have been tried were really exceptional forms and not those with which we have to deal in a practical way.

I am sure the papers which are to follow will bring out points specifically, and emphasize important things in a way which I have not been able to do, and I hope that in the discussion, and with a free opportunity for asking questions, we all will gain a great deal of valuable information.

The Use of Copper Sulphate to Guard Against Typhoid Fever Epidemics Coming from Unfiltered Surface Water Supplies.

BY PROF. W. P. MASON, TROY, N. Y.

Mr. President and Gentlemen, — I am somewhat embarrassed by the magnitude of the title of my paper, which I had not seen before. I have but a few words to say on this subject and will occupy but a minute or two.

And, first of all, I wish to state that I have nothing but the pleasantest things to say with reference to the use of copper sulphate for the purpose of killing algal growths. I had expected to be instructed to no small degree on the question of killing typhoid germs, but that subject was hardly touched upon in Dr. Moore's remarks. There is no question whatever that we are under very great obligation to Dr. Moore and his associates for giving us some means of getting over the exceeding difficulty of algal growth; but one or two thoughts occur to me with reference to the typhoid side of the question.

You know both the daily and the scientific papers have been quite full of suggestions for the possible cure of the typhoid evil by dosing our water supplies with copper sulphate, following out the general lines already touched upon for dealing with another form of growth. Personally I should scarcely be willing to dose a

water supply for which I was responsible with the intent to kill germs of typhoid, simply because such dosing would have to be continuous. I ask you, is there not a tremendous difference between an occasional dosing, such as would rid water of these ordinary algal growths, and the continuous dosing required to dispose of an organism like the typhoid germ?

If we have a bad taste in our reservoir water, it is there but occasionally, while if we have sewage in our supply it is present three hundred and sixty-five days and nights in the year. Therefore, although the amount of copper sulphate added be small, the important point is that, when we are dealing with the typhoid germ, its addition must be continuous. I will admit that in the event of Asiatic cholera striking us, a disease which comes to us but rarely, we might turn to the use of copper sulphate to kill the germ, and be justified in so doing, because of its occasional appearance; but in dealing with typhoid fever and the general sewage question, we would be forced to apply the remedy day in and day out for a long period of time, indeed, permanently.

And again, what do we accomplish by such use, even supposing that the salt be not poisonous? What do we accomplish in the way of the reduction of turbidity, in the way of taking out the color, in the way of improving the physical appearance of the water? If our water be such that its appearance needs improving, why, the very means that we use to accomplish that result, namely, the modern filtration plant, will, of itself, remove the germs that we are anxious to get rid of without any necessity of killing the same by the addition of copper sulphate.

I very much question whether we know all that may be known with reference to the poisoning effect of copper sulphate upon the human economy. We are limited to a consideration of the effect of occasional and relatively large doses. The question here is, What would be the result should we feed our people small amounts of copper sulphate during long periods of time? That inquiry has to be, I think, still left unanswered.

I am looking forward with a great deal of pleasure to listening to what may be said during this discussion. There was one point in Dr. Moore's remarks that seemed to me especially worthy of being touched upon, namely, the resistant strain of aquatic life

about which he spoke; the suggestion that the material with which he experimented in the laboratory was possibly a little more resistant than the material as it would be found in practice. With reference to algal growths I have nothing to say, being in ignorance on the point, but as touching pathogenic germs, I have strong doubts about those of the laboratory being as resistant as the ones fresh from the excreta. It may be that there are those who will assist us to further information upon that point to-day, but it would not surprise me very greatly to find that the dose of copper sulphate which would kill the laboratory bacillus would fail to do as much for his wilder brother of the bowel.

Destruction by Copper Sulphate of Typhoid Fever Germs.

BY DANIEL D. JACKSON, MT. PROSPECT LABORATORY, BROOKLYN, N.Y.

The destruction of the germs of typhoid fever in water by means of copper sulphate has been the subject of a considerable amount of discussion during the present year, and no definite decision has been heretofore reached as to the amount of copper sulphate required for this purpose. The differences of opinion on this subject have undoubtedly been largely due to differences in the virulence of the cultures employed. The ordinary laboratory cultures which have been resuscitated by growing in beef broth have been supposed to regain their original virulence, but the experiments which are cited in this paper show that such is by no means the case, and that the highest degree of virulence is only obtained when the typhoid culture is taken fresh from the human subject directly after death.

Resuscitated typhoid cultures obtained from several prominent laboratories were experimented upon to determine the amount of copper sulphate required to destroy them. The following table gives the results obtained when the cultures were treated in distilled water with various amounts of copper sulphate:

TREATMENT OF ORDINARY TYPHOID BACTERIA IN DISTILLED WATER WITH COPPER SULPHATE.

Amount of Copper Sulphate Used.	Number of Typhoid Bacteria Remaining after 3 Hours.	after 24 Hours.
None	1 980	1 200
1–20 000 000	1 920	1 100
1–10 000 000	1 180	420
1– 5 000 000	980	265
1– 3 000 000	435	3
1– 2 000 000	0	0
1– 1 000 000	0	0
1– 500 000	0	0

It will be seen from this table that the amount required for the sterilization of such a culture is one part of copper sulphate in two million parts of water.

The table which follows shows the same treatment as in the previous table, except that sterilized Brooklyn tap water was used:

TREATMENT OF ORDINARY TYPHOID BACTERIA IN STERILIZED BROOKLYN TAP WATER WITH COPPER SULPHATE.

Amount of Copper Sulphate.	Number of Typhoid Bacteria Remaining after 3 Hours.	after 24 Hours.
None	2 300	1 640
1–20 000 000	1 450	830
1–10 000 000	1 320	120
1– 5 000 000	570	80
1– 3 000 000	120	5
1– 2 000 000	0	0
1– 1 000 000	0	0
1– 500 000	0	0

It will be seen that in both of these cases one part of copper sulphate in two million parts of water is sufficient for disinfection.

These two experiments are representative of a very considerable number of others along the same lines, but from the next table it will be seen that the results are very different from those obtained when fresh, virulent typhoid bacteria are used.

TREATMENT OF VIRULENT TYPHOID BACTERIA IN STERILIZED BROOKLYN TAP WATER WITH COPPER SULPHATE.

Amount of Copper Sulphate Used.	Number of Typhoid Bacteria Remaining after 3 Hours.	after 24 Hours.
None	82 000	68 000
1–3 000 000	23 000	12 300
1–2 000 000	18 400	1 300
1–1 000 000	12 800	450
1– 500 000	560	23
1– 100 000	8	2
1– 50 000	0	0

It is evident from the above figures that typhoid bacteria of the attenuation usually found in water are destroyed by copper sulphate in the proportion of one part to two million parts of water. These results, however, are not obtained when fresh, virulent typhoid germs occur in water. A strength of one part copper sulphate to fifty thousand parts of water is then required. It is, however, entirely impracticable and unsafe to use such a strength in the treatment of drinking water, as an amount greater than one part per million can be detected by taste, and if taken constantly would be likely to produce a physiological effect upon the consumer.

Very considerable light is shed upon the subject of typhoid treatment by experimenting upon the *bacillus coli communis*. This bacterium is present under normal conditions in the human intestine and is very closely comparable with the typhoid bacterium in respect to its behavior with antiseptics.

After having obtained very similar results upon the *bacillus coli* by the use of copper sulphate, an experiment was made upon a water supply pond in the borough of Brooklyn containing sixty millions gallons of water. The water of this pond is used only after mechanical filtration, and under such circumstances all copper has been found to be removed. The accompanying diagram, Fig. 1, shows the removal of *bacillus coli* from the pond by means of a treatment of one part copper sulphate to two million parts of water. The lower portion of the chart shows the positive presumptive tests for *bacillus coli* obtained in dilutions of 0.1 cc.,

1 cc., and 10 cc. The middle line shows the total amount of gas obtained in the three presumptive tests for each day, and the top line shows the total number of bacteria present throughout the experiment. The results show that *bacillus coli* of the attenuation found in water is (until receiving further contamination) completely removed by a treatment of copper sulphate in the proportion of one part to two million parts of water.

Little or no effect is produced upon the common bacteria in water by such a strength of copper sulphate, and unless the copper

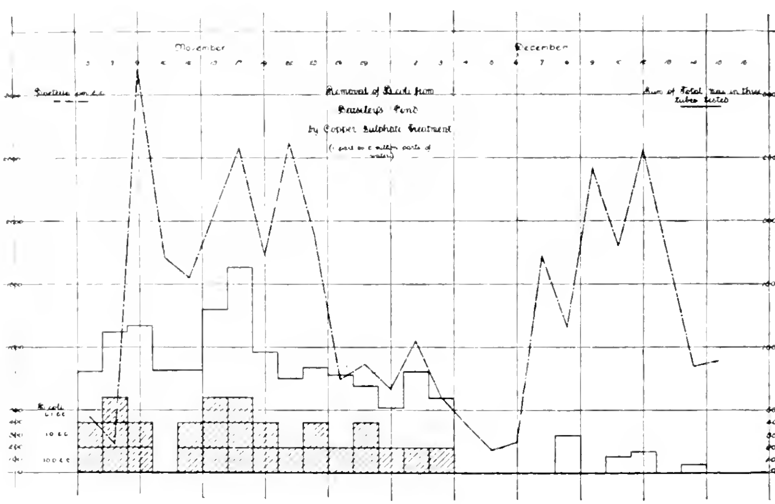


FIG. 1.

is rapidly removed by precipitation the common bacteria usually increase enormously in numbers, especially when a considerable amount of food has been rendered available by the killing off of large numbers of algæ by means of the copper treatment.

In cases of epidemic from typhoid fever in a water supply, the disease bacteria may be greatly attenuated and rendered much less dangerous by a treatment of one part copper sulphate to one million parts of water. It is probable that this treatment will kill off all typhoid germs of the usual attenuation found in water, but at no time should more than this strength be used.

The Use of Metallic Copper for the Purification of Drinking Water.

BY PROF. HENRY KRAEMER, PHILADELPHIA.

Before giving the results of my experiments with copper foil in destroying certain intestinal organisms, I desire to give some general observations with regard to the use of copper in the purification of water supplies, as the subject presents itself to me.

What I wish to bring out is that there appear to be distinct uses for copper foil and for copper sulphate or the salts of copper, and also that there is a proper time and place for the use of these.

Copper foil seems better adapted for use in the average household, and may be used when the drinking water supplied to a community is a diluted sewage, as it is in a number of places.

Salts of copper seem better adapted for disinfecting the discharges of typhoid patients, treatment of sewage, and the purification of contaminated water in reservoirs.

Theoretically, there should be no need of treating either the water in a reservoir (except where there is algal growth) or that which is supplied the householder from the city supply, except when there is contamination as a result of accident, as sometimes happens, granting that the sources of contamination have been properly safeguarded.

The discharges from typhoid patients being the source of the disease, it is obvious that the disinfection with copper sulphate should begin here, and physicians should give instructions accordingly. If universal attention were given to this matter there can be little doubt that the spread of typhoid fever would be prevented almost entirely. But as the matter cannot be absolutely controlled the next best thing is to *disinfect the sewage*.

That certain organisms manifest a specific sensitiveness towards copper was first pointed out by Naegeli. Following the lead of Naegeli, Israel and Klingmann (1897) showed that copper foil has a marked toxic effect on certain bacteria, as *bacillus coli* and the organisms producing typhoid fever and cholera. To Moore and Kellerman (1904) belongs the credit of first showing the application of the results obtained by Naegeli (on algæ) and Israel and Klingmann (on bacteria) in the purification of water supplies.

As the methods used in my work have been published and are readily accessible, it will probably be sufficient to call attention to some of the main features of the work.

1. The copper used was in the form of sheet copper or copper foil, pieces approximately 9 cm. square being used to each 1 000 cc. of water.

2. The organisms upon which we experimented were *bacillus coli* and *bacillus typhi*, twenty-four-hour bouillon cultures being used.

3. The water used in the experiments included filtered, distilled, and tap water, all of which were sterilized in an autoclave prior to adding the cultures and copper foil.

We found in nearly every experiment which we conducted that in the water containing the typhoid or colon organisms, and to which the copper foil was added, these organisms were destroyed in from two to four hours.

We also found in the parallel experiments which we conducted that in the water to which copper foil was not added, the typhoid and colon bacilli continued to grow and even multiply for months, except in the case of water filtered by means of a filter attached to an ordinary copper faucet. In the latter instance the typhoid organisms were destroyed in two to four hours, just as though copper had been added to the water, whereas the colon bacilli continued to grow, but not as rapidly as in distilled or tap water. This peculiar inhibiting action of the filtered water we subsequently proved was due to a property acquired by the water in its slow passage through the copper spigot to which the filter was attached. That the inhibiting action of the filtered water was due to its contact with the copper spigot, is shown by the fact that when we used a filter in which contact with copper was avoided, the typhoid organisms continued to grow the same as in distilled and tap water.

Later experiments showed that contact of the copper foil with the water for a very brief period of time was sufficient to affect these organisms. We found, for instance, that if the copper foil were allowed to remain in distilled water for one to five minutes, the typhoid organisms were completely destroyed within a few hours.

In a paper presented to the American Philosophical Society, the results of my work along this line are summarized as follows:

Certain intestinal bacteria like colon and typhoid are completely destroyed by placing clean copper foil in water containing them, or by adding the organisms to water previously in contact with copper foil.

The toxicity of water to which either copper coins or copper foil has been added is probably due to a solution of some salt of copper, as first suggested by Naegeli.

The copper is probably in the form of a crystalloid rather than that of a colloid, as it has the property of permeating the cell walls and organized cell contents of both animals and plants, thereby producing the toxic effects.

While the effects produced by the oligodynamic action of copper are apparently different from those of true chemical poisons, the difference is probably in degree only and not in kind.

Certain lower organisms, including both plants and animals, possess a specific sensitiveness to minute quantities of copper, and it has been shown that they are not restored on transferring them to water free from oligodynamic properties.

Oligodynamic solutions of copper are obtained by adding either copper coins, copper foil, or salts of copper to water; when copper foil is used, sufficient copper is dissolved by the distilled water in one to five minutes to kill the typhoid organisms within two hours.

A solution of copper may lose its toxicity by the precipitation of the copper as an *insoluble salt* or *compound;* by its *absorption* by *organic substances;* or by *absorption* by *insoluble substances.*

The oligodynamic action of the copper is dependent upon temperature, as first pointed out by Israel and Klingmann.

The effects of oligodynamic copper in the purification of drinking water are in a quantitative sense much like those of filtration, only the organisms removed, like *bacillus typhi* and *bacillus coli*, are completely destroyed.

THE EFFECTS OF WATER TREATED WITH COPPER ON MAN.

While it has been conclusively shown that exceedingly minute quantities of copper are toxic to typhoid organisms, still the question is raised by some as to the toxic effects on man when copper or its salts are used in the purification of drinking water.

In commenting on a paper of mine on "The Efficiency of Copper Foil in Destroying Typhoid and Colon Bacilli in Water," a reviewer writes as follows: "While recommending the use of copper foil for the purification of drinking water, the writer adduces no proofs as to freedom from toxic effects when water so purified is taken into the system over a considerable period of time." My reason for not taking up the pharmacological phase of this question heretofore has been that my own experiments in the consumption of water treated with copper foil did not extend over a sufficient period of time to warrant me in making any statements in regard to the effects of water so treated. Then, too, I felt that the statements of pharmacologists and physiologists were conclusive as to the probable harmlessness to man of copper when used in the proportions necessary to purify water containing typhoid organisms. But since there seems to be some objection in certain communities to the drinking of water treated with copper, I have deemed it advisable to give my own experience in connection with this subject.

For nearly a year all of the drinking water consumed in my home has been treated with copper. A strip of copper foil, or sheet copper, nine inches square, is placed in a vessel containing from three to four quarts of water and allowed to remain from four to eight hours. The foil is first cleaned with powdered pumice, and retains its luster for weeks unless the water contains a considerable quantity of sediment, and provided the quantity of water is renewed immediately each time upon drawing off the sterilized or purified water. On account of the varying amounts of sediment, we find it desirable to filter the water before treating it with copper foil. Up to this time no ill effects have been noted from drinking the water so treated, and, in fact, our general health may perhaps be said to be better than usual, in that we have not had to consult a physician during this time. Another interesting observation is that the water being more palatable than boiled water, we consume larger quantities, which possibly has some influence on the general bodily condition.

Believing that many vegetables may also be a source of infection, we take the precaution either to wash the vegetables to be eaten raw with copper-treated water, or to place them, particularly

in the case of lettuce and celery, in a vessel of water along with a strip of clean copper foil and allow them to remain from two to four hours with occasional agitation.

The use of copper vessels would be more convenient, but of course is more expensive. I have also thought that water pitchers and tumblers might be partly lined with copper foil.

From my own experience and observations, together with those of others, we may draw certain general conclusions, which I have summarized as follows:

It is pretty well established that the typhoid organism is disseminated not only through water, but also through air and food, and may retain its vitality for a considerable period of time.

Typhoid organisms in water are eliminated by filtration, boiling, and by certain biochemical methods. Of the latter, the use of copper, as proposed by Moore and Kellerman, is probably the most efficient and at the same time the most practicable.

While exceedingly minute quantities of copper in solution are toxic to certain unicellular organisms, as bacteria, it is safe to assume that the higher plants and animals, including man, are unaffected by solutions containing the same, or even larger amounts of copper.

There being a number of factors which tend to eliminate the copper in solution, it is hardly likely that there would be any copper in solution by the time the water from a reservoir reached the consumer if the treatment of the reservoir were in competent hands.

Many plants contain relatively large quantities of copper, and when these are used as food, some of the copper is taken up by the animal organism, but there are no records of any ill effects from copper so consumed.

The Toxicology of Copper and Its Relation to the Copper Treatment of Water.

BY HERBERT E. SMITH, M.D.*

So firmly imbedded in the popular mind is a belief in the poisonous action of copper, that the question of the toxicology of copper

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is one that presses for an answer wherever it is known that copper sulphate is to be used in a public drinking water. There are generally objections to a chemical treatment of drinking water, but because of the common belief, people may justly demand a positive answer to the question, — Is the use of copper in our drinking water likely to be injurious?

If I should attempt to give a review of the literature of the toxicology of copper, I should have to present a wearisome mass of conflicting opinion and statements of alleged facts, which would but end in confusion. Therefore, I will confine myself to a brief statement of the matter as it appears from the experimental work and observations of the past few years.

In order to understand the toxicology of copper, one must distinguish sharply on the one hand between the irritant action which copper salts produce on the mucous membranes of the stomach and intestines when they are swallowed, and on the other hand, the effect which they produce upon the cells of the interior organs of the body after they have been absorbed into the blood.

The first effect is that which would be produced on man by the ingestion of a large dose, *i. e.*, several grams of copper sulphate, and would be manifested by nausea, vomiting, colic, diarrhea, and the other symptoms of a gastro-enteritis. These are the symptoms most commonly seen in copper poisoning in man, and usually constitute about all there is in an attack of this sort, for rarely does it happen that acute systemic poisoning occurs in man.

That copper is capable of producing profound systemic poisoning, however, is abundantly shown by the laboratory experiments of Tschisch, Lehmann, Filehne, and others, in which the copper compounds were introduced by the hypodermic method into rabbits, cats, and dogs. The symptoms produced in this way are referable to the direct action of the poison on the protoplasmic contents of the cells in the various organs affected. The chief symptoms are muscular paralysis, jaundice and other signs of fatty degeneration of the liver, hematuria and other signs of an acute toxic nephritis, destruction of blood corpuscles, and usually disturbance of the functions of the alimentary canal. Death usually occurs as the result of cardiac and respiratory paralysis.

Systemic poisoning *may* be caused by absorption from the

alimentary canal, as has been shown by experiments on sheep and other animals that do not vomit. It appears, however, that the dose must be large enough to produce gastro-enteric disturbances. It is, therefore, possible to get both the irritant and the systemic effects by repeated administration of moderately large doses.

With lead and mercury, repeated small doses produce severe systemic poisoning; this appears not to be the case with copper.

Kunkel, who has written perhaps the best modern systematic toxicology, says that chronic poisoning with copper, in the sense that we have it with lead and mercury and in which it has been claimed for copper, does not exist; that is, the administration of small quantities of copper continued through a long time does not produce deleterious results.

It is true that one may find in medical literature some cases described as chronic copper poisoning, but such are admittedly rare, and on close analysis appear to be of mistaken diagnosis.

In the support of the statement that copper does not produce chronic poisoning may be advanced the numerous experiments on man himself. Thus one observer took from ten to twenty milligrams of copper in the form of copper sulphate daily for eighty days and another for fifty days, with no ill effect. Doses of over sixty milligrams, however, produce some alimentary disturbance and would doubtless prove injurious if long continued. The form in which copper is taken has much to do with its effect. The simple salts like the sulphate and acetate are most active, while the compounds formed between copper and albumins are much less active.

The conclusions then which may be deduced from the recent literature are, that a single large dose of a salt of copper may produce in man acute irritant poisoning, followed sometimes by systemic poisoning; that repeated moderate doses produce a subacute poisoning, due largely to the systemic effect; and that repeated small doses, say from ten to thirty milligrams administered by the mouth, cause no poisoning even when continued many days.

The question before us, therefore, turns largely on the dose, and on the form and manner of ingestion. For the purpose of

obtaining a probable dose which might result from the use of copper sulphate in a reservoir, let us assume the use of one part of copper sulphate per million of water. This means that one kilogram of water would contain one milligram of copper sulphate, or about one quarter of a milligram of metallic copper. An assumption of a daily maximum use of two kilograms of water, something more than two quarts, would give a daily dose of one half a milligram (0.5 mgm.) of copper, or about one one hundred thirtieth part of a grain. This is a quantity which when administered by the mouth must be regarded as insignificant as a toxic agent on man, and would be so even if increased several fold. Ordinary precaution on the part of the operator would induce him to avoid a concentrated solution in the vicinity of a water intake, so that this danger of a possible larger dose is no necessary feature of the application of the method.

I have assumed that the copper was in solution as sulphate in the water, but experience teaches that the copper rapidly disappears from solution after the treatment. This means, of course, that the copper is precipitated in some form, and the question may arise as to the danger from concentration of the copper in the form of sediment. This is a possibility and therefore the form in which the copper is precipitated is of importance. It seems probable that the copper is precipitated in albuminous combinations, that is, that it is absorbed by the albuminous constituents of the microscopic organisms in the water. The basis for this suggestion may be deduced from the following considerations. The most delicate tests which the chemist has for the detection of copper are hydrogen sulphide and potassium ferrocyanide. The limit of delicacy of these reagents is given by Professor Wormley as about one part of copper oxide in one hundred thousand parts of solution. The only precipitants uniformly present in natural water are the alkalies, and surely they could not precipitate the copper from a solution of one part per million, for they are much less delicate than the reagents mentioned. But suspended albuminous matter might absorb it, and that this action does take place is indicated by the fact that the dead organisms collected in reservoirs after the treatment, have been found to contain considerable quantities of copper. This method of

precipitation is important because these albuminous compounds have been found to be of low toxic power, and, therefore, do not materially increase the danger of poisoning to those using the water.

Support of the assertion that such small amounts of copper as are involved in reservoir treatments are not toxic, may be drawn from the common use of articles of food containing relatively larger quantities of copper. Thus grain and vegetables grown in copper-containing soils are found to contain notable quantities of this metal. Wheat has been found to contain from three to ten milligrams of copper per kilo, and various green vegetables from three to twenty milligrams. Canned vegetables, especially peas, are frequently treated with copper sulphate to preserve their green color. From twenty to thirty milligrams per kilo are common amounts, and frequently much more has been found, yet such materials have been widely used without deleterious effect. Copper is also frequently introduced into food through the use of copper and brass utensils. Indeed, so commonly are articles of food contaminated with copper that Gautier has estimated that from four to five milligrams of metallic copper are ingested daily by most men in their food.

From all of these considerations, one may conclude that there is no danger to the public health from the use of copper sulphate in drinking waters as it is applied for ridding them of the various microscopic algæ.

There are one or two other thoughts which occur to me. First, why is it that if copper is so poisonous to man and the lower animals when injected into the blood, small quantities taken into the stomach do not have any deleterious effect? I believe it is merely a question of absorption. If injected into the blood small quantities of copper are poisonous to mammals and doubtless to man. If taken into the stomach, however, the system is protected by the albuminous constituents of the blood and by the albuminous envelopes through which the copper must pass before it gets into the blood. That is the explanation and the only one I can see why copper in small doses is not poisonous to man — it does not get where the poisonous effect can be produced.

Why is it, if copper in these very small quantities is not poison-

ous to man, that it is so highly poisonous to organisms which we find in water? Why is it that uroglena will succumb even to one part of metallic copper in sixty, seventy, or eighty million parts of water, as I have seen it in actual experiments? It must be wholly a question of the way in which the copper can get at the organism. I cannot conceive that the protoplasmic material of uroglena is substantially different from that of many other related forms; but I can conceive that there is a difference in the ease with which the copper can penetrate to the cell, and I believe we shall find that that is the main reason why we have the selective difference which has been referred to.

The question of fish is one which I am not quite ready to deal with. I do not see why there should be such a marked difference as has been referred to in the susceptibility of different fish. I do believe that fish are more susceptible to copper than most other animals, and they have been proved to be by experiments, because fish have a better opportunity to absorb it than other animals. They have a very good absorbing apparatus in their gills, and I have sometimes thought they might get the copper in that way in very much larger quantities; but why the pickerel should have so much more selective action than the black bass I can see no present explanation for.

Behavior and Uses of Copper Sulphate in the Purification of Hard and Turbid Waters.

BY JOSEPH W. ELLMS, CINCINNATI, OHIO.

The proposed general use of copper sulphate in connection with the filtration of public water supplies, in order to further safeguard the purity of the effluent through the germicidal properties of this compound, immediately raises the question as to the character of the chemical reactions which occur when copper sulphate is introduced into a natural water. In the filtration of waters through slow sand filters without the use of chemical coagulating compounds, the applied copper sulphate would react with the natural constituents of the water; but in the case of waters coagulated and filtered with the assistance of chemicals, the latter would

also enter into the changes which would take place. From a few experiments made by the writer the general character of these reactions appeared to be as follows:

The bicarbonates of lime and magnesia naturally present in most waters are the compounds which give to them their temporary hardness. It is with these salts that the copper sulphate reacts. Since no neutral carbonate of copper is known, the probability is, that a basic carbonate of copper is first formed, which may gradually break up into an insoluble cupric hydrate and free carbonic acid. The reactions which take place may be represented as follows:

(1)	$2CuSO_4$	+	$2CaH_2(CO_3)_2$	=	$CuCO_3.CuO_2H_2$	+	$2CaSO_4$	+	$3CO_2$	+	H_2O.
	Copper sulphate	+	Bicarbonate lime	=	Basic carb. copper	+	Calcium sulphate	+	Carb. acid	+	Water

The basic carbonate of copper may possibly decompose according to reaction (2).

(2)	$CuCO_2.CuO_2H_2$	+	H_2O	=	$2CuO_2H_2$	+	CO_2.
	Basic carb. copper	+	Water	=	Copper hydrate	+	Carbonic acid

The hydrate of copper is said to be an insoluble compound. The basic carbonate of copper is more or less soluble in water containing carbonic acid.*

The experiments made appeared confirmatory of the general character of the reactions as outlined above. The precipitate was colloidal in character, separating slowly and imperfectly from the water. About 40 or 50 per cent. of the copper sulphate applied to the water could be detected in solution if the treated water was filtered within ten or fifteen minutes after applying the chemical. If three hours elapsed, however, before filtering, from 70 to 95 per cent. of the copper was removed, and at the end of twenty-four hours no copper could usually be detected in the filtered water by the colorimetric test employed.

These results seem to indicate, that either a slow deposition of the basic carbonate of copper from its supersaturated solution

* Comey's Dictionary of Chemical Solubilities.

was taking place, or that it was being converted from a soluble form due to the free carbonic acid present in the water, into an insoluble hydrate of copper. Whether the basic carbonate of copper or the hydrate is the end product of the reaction is somewhat uncertain from the evidence obtained. Practically it is of no material importance. The point to be noted is, that it was plainly evident that the copper compound first formed was soluble to a certain extent, and that its solubility slowly diminished as more time elapsed, and finally it was practically all precipitated.

Other experiments appeared to indicate that the solubility and non-precipitation of the applied copper was largely due to the free carbonic acid either naturally present in the water or liberated by the mutual decomposition of the copper sulphate and calcium and magnesium carbonates. By adding caustic lime to the water after introducing the copper sulphate, in order to combine with all of the free and half-bound carbonic acid in solution, all of the copper was very soon precipitated, and none was found in the filtered sample. If, however, all of the free and half-bound carbonic acid was not removed by caustic lime, then only a portion of the copper was immediately precipitated; although after three hours had elapsed the whole of the copper appeared to have passed out of solution. For example, when no lime was used, only 50 per cent. of the applied copper was removed within ten or fifteen minutes after treatment; when a reduction of 23 per cent. in the free and half-bound carbonic acid was effected with caustic lime, 88 per cent. of the copper was removed; and when 100 per cent. of the free and half-bound carbonic acid was eliminated, no copper was detected in the filtered sample. When 44 per cent. of the free and half-bound carbonic acid had been removed from a water in another experiment and the water allowed to stand for three hours, all of the copper was found to have passed out of solution.

One can readily enough conceive of a direct reaction occurring between the basic carbonate of copper and the caustic lime added as follows:

$$CuCO_2.CuO_2H_2 + CaO_2H_2 = 2\,CuO_2H_2 + CaCO_3.$$

In this case we have the basic carbonate of copper converted into the insoluble hydrate.

The influence of organic matter in preventing the precipitation of copper is well known. A few experiments were made by the writer in which a hard water was artificially colored, in one case with a caramel solution and in another with a leaf infusion, in order to imitate a natural colored water. In both experiments only 70 per cent. of the applied copper sulphate was precipitated in three hours time, whereas in the same water without the coloring matter 90 per cent. of the copper was precipitated. The residual amount of copper sulphate in each of the " colored water " experiments was between seven and eight parts per million. In another experiment in which ten parts per million of copper sulphate had been added to a hard water colored with a leaf infusion, five parts per million were found at the end of sixteen days. This indicates a reduction of only 50 per cent. of the amount of copper sulphate applied. It would appear from these results that the quantity of copper held in solution by organic matter may vary, and that quantities as great as five parts per million may be retained in solution for long periods of time.

It was further found that by adding caustic lime to the water in sufficient amount, practically all of the copper was precipitated. In an experiment where 44 per cent. of the free and half-bound carbonic acid had been removed by caustic lime, no copper could be detected in the filtered sample. In another experiment where the copper sulphate had been in solution in a colored water for over two weeks, an addition of caustic lime at the end of this period to remove a portion of the free and half-bound carbonic acid did not appear to entirely remove the copper. Probably where a complex stable compound has been formed between the copper sulphate and the organic coloring matter, it would be necessary to render the water slightly caustic in order to decompose the copper compound and cause its precipitation.

So far as these few experiments indicate conditions which may exist in natural waters when treated with copper sulphate on a large scale, the following conclusions may be drawn:

1. That copper sulphate applied to a water having bicarbonates of lime and magnesia in solution, reacts with these salts to produce a compound which is at first partially soluble in the water, and which only slowly becomes insoluble and passes out of solution.

2. That probably within twenty-four hours all of the copper sulphate applied to a hard water having practically no organic coloring matter and containing but little free carbonic acid, is converted into an insoluble form and can be filtered out.

3. That organic coloring matter tends to retain a portion of the copper and to prevent its precipitation, and that its complete elimination is not effected for a considerable period of time.

4. That by the use of enough caustic lime to remove the free and half-bound carbonic acid, the applied copper sulphate can be rendered insoluble in hard waters containing little organic matter, and that colored waters may require an excess of lime so that the water is caustic in order to remove all of the copper.

5. That the colloidal character of the precipitated copper compounds renders them difficult to remove by sedimentation alone, and that the filtration of the water is probably necessary for their complete and rapid removal.

There is as yet comparatively little information available in connection with the use of copper sulphate in filtration, from which conclusive evidence as to its efficiency as a bactericidal agent can be drawn. The evidence at hand, however, appears to indicate that we have in this compound a valuable aid to the purification of polluted waters. There are one or two points in connection with its use in filtration which may be profitably discussed in the light of the few data available. In the first place it must be conceded that copper sulphate in sufficient quantity will destroy certain disease-producing bacteria, such as the bacilli of typhoid fever and cholera. It will also kill the intestinal bacillus *B. coli communis;* but that it has any selective action in removing from water any of the above organisms in preference to the ordinary water bacteria, as has been suggested, the writer does not believe is sufficiently well proven. When copper sulphate is applied to a water containing only the common water bacteria, it would naturally exert its greatest destructive action upon the weaker individuals. The disease-producing germs being in an unnatural environment when in water, are probably the first to succumb to the toxic action of the copper sulphate on account of their debilitated condition. But it seems just as likely that the weaker water bacteria are also destroyed at the same time,

leaving only the hardier individuals. The toxic effect of the copper is thus probably selective only in the sense of its being more destructive of the weaker organisms. This appears to be the only rational explanation for certain results observed in recent tests of two municipal filtration plants where copper sulphate was used, and at which the writer was present.

The amounts of copper sulphate which a number of experimenters have reported as necessary to destroy such bacterial forms as *B. coli* and *B. typhi*, are so much larger than those reported by other investigators and so much greater than appeared effective in the tests of the municipal filtration plants referred to above, that some explanation seems necessary. As pointed out by Moore and Kellerman,* the conditions under which earlier investigators carried on their experiments were far different from those existing in most public water supplies. The more recent experiments appear to indicate that quantities of copper sulphate ranging from two to ten parts per million of water are toxic to pathogenic or allied forms. The presence of much organic matter undoubtedly retards, if it does not even prevent, the action of the copper compounds on the bacteria, and thus requires a larger quantity of copper to be used than that cited above to produce the desired results. The length of time required for contact of the organisms with copper compounds in order to destroy them, appears also to be variable. The factors influencing the quantity of copper sulphate necessary to destroy bacteria, therefore, are so variable that only within rather wide limits can the amount which would be toxic to any particular organism, be stated.

When a water which has been treated with copper sulphate is filtered through a sand filter, the insoluble copper which has not settled out in preliminary settling basins, passes on to the sand bed and is deposited. It is evident that the longer the filter is in operation the greater becomes the quantity of copper deposited on the surface of the sand bed. It is through this deposit of copper that all the water is passing which is being filtered. The deposited copper thus forms a danger zone through which all the bacteria coming upon the bed must pass. Even though the original concentration of the applied copper sulphate may be very small, the

* Bulletin No. 64, page 29, U. S. Dept. Agriculture.

continuous deposition of insoluble copper compounds going on at the surface of the sand has virtually the effect of a continually increasing concentration.

The efficiency of the copper sulphate depends not only upon the condition of the organism and the character of the water in which they are disseminated, but on the opportunity afforded for the coming together of the organism and the toxic copper compounds. It, therefore, seems very reasonable to expect that water treated with relatively minute quantities of copper sulphate will be effective when the water is subsequently filtered, because the sand bed offers not only a chance for increasing quantities of copper to be deposited, but affords a place where actual contact between the organism and the toxic copper compounds can take place.

The copper compounds precipitated are probably always colloidal in character. It has been pointed out recently by one investigator,* that in this form it has a more rapid toxic effect on typhoid organisms than on the ordinary water bacteria. The precipitation of the copper in the colloidal form is for some reasons unfortunate, since in this condition it settles out very slowly and imperfectly. This property renders it much more difficult to eliminate from a water which is not subsequently filtered; and it can be readily understood that in the case of a water carrying considerable organic matter, traces of copper might be retained for a long period of time. It is not the writer's belief, however, that these traces would be in the least harmful to persons drinking the water.

The use of copper sulphate with chemical coagulating compounds somewhat complicates the problem of its final disposal. If sulphate of alumina is used with copper sulphate the increased quantity of carbonic acid produced by the mutual decomposition of the sulphate of alumina and bicarbonates of calcium and magnesium would have a retarding action on the precipitation of the copper. Where caustic lime and sulphate of iron are employed as coagulants, the former by removing the carbonic acid would tend to aid the precipitation of the copper. As was indicated by

* "A Study of the Action of Colloidal Solutions of Copper upon Bacillus Typhosus," by A. H. Stewart, Am. J. Med. Sci., 129, 760–769.

the experiments recorded in the first portion of this paper, the addition of lime also assisted in hastening the removal of the applied copper. The introduction of lime, therefore, affords a means of eliminating copper from soft waters and from colored waters and thereby renders its use in slow sand filters a possibility.*

While the evidence in regard to the value of the use of small quantities of copper sulphate for its bactericidal effect in connection with filtration is limited, still that which has been produced is worthy of careful consideration. A thorough scientific investigation of the whole question, undertaken on a large scale, is especially desirable in so far as it relates to water purification, in order that we may know the advantages as well as the disadvantages which result from its employment as a disinfectant of public water supplies.

The Use of Copper Sulphate in Water Filtration.

BY H. W. CLARK, CHEMIST, STATE BOARD OF HEALTH, BOSTON, MASS.

An experiment was begun at the Lawrence Experiment Station in May, 1904, in order to test the value of copper sulphate as an aid in the purification of polluted water. In this investigation a large experimental filter, 17 feet 4 inches in diameter and containing 2½ feet in depth of good filter sand, was used. Before the beginning of the copper sulphate experiment, this filter had been in use for eleven years, filtering Merrimac River water. Beginning May 17, 1904, however, copper sulphate was added to the raw water applied to this filter, the amount used at first being 1 part of the sulphate in 1 000 000 parts of water, and the greatest amount used during the year of experiment was 1 part in 133 000 parts of water.

The copper sulphate was applied directly to the water upon the surface of the filter, but the volume of water always above the sand allowed a storage of water, after introduction of the sulphate, ranging from five and one-fourth hours to slightly more than eight

* This fact was pointed out by Moore and Kellerman in Bulletin No. 64, U. S. Dept. Agriculture.

hours, varying, of course, with the rate of filtration at which the filter was being worked.

Examination of the sand of the filter from time to time during the experiment and after the experiment had ended, showed the accumulation of a large amount of copper in the sand, and also showed that the copper penetrated the entire depth of the filter. At the end of the experiment, the amount of copper in the surface sand of the filter was 22.8 parts per 100 000; at a depth of 12 inches, 7.6 parts per 100 000; and at a depth of 24 inches, 6.8 parts per 100 000. Giving these results in terms of copper sulphate, the surface sand contained 89.5 parts of copper sulphate per 100 000; at 12 inches there were 79.8 parts present, and at 24 inches there were 26.6 parts present.

Analyses of the effluent of the filter showed that this effluent contained copper, calculated as copper sulphate, varying in amounts at different times from 1.2 parts per million parts of water to 5.8 parts per million parts of water. At the end of August, 1905, three months after we had ceased to add copper sulphate to the applied water, the effluent contained copper, calculated as copper sulphate, to the amount of 3.7 parts per million parts of water, showing that copper was continually being taken into solution from the deposit within the filter.

The actual volume of water passed through this filter daily varied from 14 000 to 26 000 gallons, and the rate of filtration varied from 2 800 000 to 4 700 000 gallons per acre daily.

In connection with this work, experiments were made in regard to the rate of sedimentation of copper sulphate after being mixed with water in large tanks at the Experiment Station, using, of course, water of the same character as that used in the filtration experiment; and in one of these sedimentation experiments it was found that there was practically no sedimentation of the copper until after a period of twenty days; in one, a reduction of 50 per cent. in fifty-four days; in one, a reduction of about 60 per cent. in sixty-two days; and in one, a reduction of 58 per cent. in twenty-one days. No sedimentation occurred in periods of twenty-four or forty-eight hours.

If, therefore, in this filtration experiment, a sedimentation tank had been placed between the point of application of the copper

sulphate and the filter, a normal period of sedimentation would have effected little copper removal, and practically all the copper not passing through the filter and appearing in the effluent would have collected upon the filtering material.

During the entire period of this investigation, samples of the water passing to the filter and the effluent of the filter were taken daily for bacterial examination. The bacterial results obtained from the filter during this experiment when compared with those obtained during the year previous to the application of copper sulphate to the raw water, show no gain in bacterial removal on account of the use of the copper sulphate, but rather the reverse. During the year previous to the use of copper sulphate, the raw water contained 8 300 bacteria per cubic centimeter and the effluent, 73 bacteria per cubic centimeter — or a bacterial efficiency of 99.12 per cent. During the year of copper sulphate treatment, the raw water contained 7 400 bacteria per cubic centimeter and the effluent of the filter, 114 per cubic centimeter — a bacterial efficiency of 98.5 per cent., 0.62 of one per cent. less than during the previous year. During both years practically every cubic centimeter sample of the raw water that was tested contained *bacillus coli*. The effluent of the filter during the year before the copper treatment contained *bacillus coli* in 13.5 per cent. of the cubic centimeter samples examined, and during the year of copper treatment it was found in 26 per cent. of the cubic centimeter samples examined: samples, of course, being taken daily. Besides the poorer bacterial results obtained, the filter was less efficient in producing an effluent free from organic matter.

Summarizing, it can be said that poorer results in water filtration were obtained when using copper sulphate than when operating the same filter without the use of the copper sulphate; a poorer effluent, organically, was obtained, and there was an accumulation of copper upon the sand in the filter that would eventually — if copper, in the form in which it remains upon the sand, has any strength at all as a bactericide — reduce the efficiency of the filter very greatly; that is, the biological actions upon which good results with slow sand filters depend would be badly impaired.

The Use of Copper Sulphate for Reducing the Pathogenicity of Sewage and Sewage Effluents.

BY GEORGE A. JOHNSON, ENGINEER IN CHARGE, SEWAGE TESTING STATION, COLUMBUS, OHIO.

There are two ways in which the sewage of large communities is disposed of at the present time. Briefly, these methods may be referred to as: First, by dilution, that is, by the dispersion of the sewage in its raw state in large bodies of water; and second, by artificial methods of purification, especially filtration, and the subsequent dispersion of the effluent in water.

Current methods for the artificial purification of sewage may be divided for present purposes into two classes wherein fine-grain and coarse-grain filtering materials, respectively, are made use of. The former processes embrace broad irrigation fields, or more limited sandy areas of selected soil, while the latter processes include the contact filter and sprinkling filter, both of which have been developed during the past ten years. The fine-grain filters yield effluents of a materially higher grade of purity than do those composed of coarse-grain material. In a general way, the former processes may ordinarily be expected under favorable conditions to remove upwards of 99 per cent. of the bacteria contained in the sewage. The coarse-grain filters, on the other hand, which are especially serviceable in making sewage non-putrescible, will remove perhaps in the neighborhood of 60 to 75 per cent. of the bacteria. Where these filters treat the effluent of a septic tank in which are removed about two thirds of the bacteria in the raw sewage, the total bacterial purification approximates 90 per cent.

The available data indicate that the removal by either process of pathogenic and non-pathogenic forms is in fairly direct proportion, generally speaking. In studying the effect which these remaining forms of pathogenic bacterial life in sewage effluents may have upon the water supply of neighboring cities, it is important to obtain light upon the longevity of the typhoid bacillus in this connection.

Self-purification of streams, or more strictly speaking, the length of life of the typhoid bacillus in water, is a question most intimately related to subjects having to do with the pathogenicity of sewage effluents. As to methods for destroying these

pathogenic forms, two may be prominently considered, namely: first, their destruction through natural causes in water; and second, their destruction by germicidal chemicals. Although somewhat foreign to the subject of this paper, it is thought that perhaps the information recently obtained at the Columbus Sewage Testing Station upon the question of the methods of testing the longevity of the typhoid bacillus in sewage and water may be of interest in this connection.

LONGEVITY OF THE TYPHOID BACILLUS IN SEWAGE AND WATER.

Without going into a lengthy discussion of the literature bearing upon this question, it may be said that the researches of the Massachusetts State Board of Health [1] at the Lawrence Experiment Station indicated that the typhoid bacillus lived in river water in decreasing numbers for at least about three weeks. Sedgwick and Winslow[2] showed with considerable clearness that certain resistant forms of the typhoid bacillus will live for an almost indefinite period of time in still water, ice, or moist earth. Horrocks[3] concludes that typhoid will live in sterile sewage for sixty days, but that in unsterilized sewage typhoid will die out in fourteen days. Pickard [4], in a study of the longevity of the typhoid bacillus at Exeter, found that about 99 per cent. of these organisms died out in fourteen days in septic sewage. Martin [5] showed that in sterile soil containing sewage matters, typhoid bacilli were able to survive for four hundred and fifty days, but in unsterile soil of a similar character he places the limit of longevity at fifty days. Karlinski [6] states that typhoid bacilli may exist in soil for more than three months. In feces it has been found to survive for at least eight months at Canton, Mass., according to Professor Mason.[7]

Quite recently the results of two series of very similar investigations of a particularly extensive character have been placed on record. The methods of procedure in these two investigations were essentially the same, consisting in the suspension of sacs composed of collodion, parchment, or celloidin, containing known quantities of typhoid bacilli, in flowing streams of Lake Michigan water, and of crude and diluted sewages. The numbers of typhoid in small volumes of the water in the sacs were painstakingly determined at intervals by the most modern methods.

The use of these sacs was considered to be quite an improvement over tests made in bottles, in that the germs were supposed to be confined and at the same time the water within and without the sacs was interchanged by dialysis.

The results of one of these investigations[8] showed that while about 95 per cent. of the typhoid germs died out in running streams of Lake Michigan water in a week or ten days' time, after which there seemed to be practically no further reduction. In general, these data are in harmony with previously obtained information on the subject. The other investigation,[9] conducted under somewhat similar conditions, indicated that the typhoid bacilli were completely eliminated in about ten days, and that in flowing streams of crude and diluted sewage the destruction of these germs took place with even greater rapidity, all organisms of this type being destroyed under these conditions in from three to four days, according to these observations.

These somewhat conflicting data (the conclusions of Frost and of Jordan, Russell and Zeit, respectively) suggest the possibility that the collodion sacs offered less opportunity for the exit of the highly motile typhoid bacilli through the walls of the sacs than did the sacs of parchment. If this was not so, the thought presents itself that possibly after several days of service the initial integrity of the parchment sacs was impaired to an extent sufficient to permit of the escape therefrom of the typhoid bacilli. To place the results of studies of this character upon a perfectly sound basis, positive data and statements are required to show whether the initial bacterial integrity of the sacs containing the typhoid bacilli continued unimpaired throughout the experiment.

Such definite information as referred to is called for, in the opinion of the writer, for the reason that studies in this line made at the Columbus Sewage Testing Station have shown that in some instances parchment sacs which possessed perfect integrity initially, and retained it throughout the experiments, so far as their dialyzing properties were concerned, permitted the escape therefrom of *bacillus coli* when immersed in distilled water, and when submerged in flowing sewage and polluted water permitted the entrance, in a comparatively short time, of large numbers of motile bacteria, including *B. coli*. Typhoid bacilli were not

studied in this connection, but the conclusion may be justly drawn, in view of the highly motile character of the typhoid bacillus, that if other less motile forms could pass through the walls of the unpunctured parchment sacs under such conditions, there is no room for reasonable doubt regarding the ability of typhoid bacilli to act in a similar manner. The results of the Columbus studies referred to are presented in the following tables:

TABLE OF RESULTS ILLUSTRATIVE OF THE PASSAGE OF B. COLI THROUGH THE WALLS OF UNPUNCTURED PARCHMENT SACS FROM THE OUTSIDE.

Sacs Suspended in a Flowing Stream of	B. coli per c.c. in the Water Contained in the Sacs. Number of Hours the Sacs were Exposed in Current.		
	0	48	72
Crude sewage	0	320	2 000
Septic sewage	0	320	2 000
Septic sewage	0	120	1 100
Eff. of a sewage filter	0	100	2 000
Polluted water	0	0	40

TABLE OF RESULTS ILLUSTRATIVE OF THE ESCAPE OF B. COLI FROM PARCHMENT SACS WHEN IMMERSED IN VESSELS OF STERILIZED WATER.

Number of Hours the Sacs were Suspended in the Sterilized Water.	B. coli per c.c. in the Water Surrounding the Sacs. Sac: a	b	c
0	Over 1 000	Over 1 000	Over 1 000
24	0	0	0

NOTE: The dialyzing integrity of all the sacs used in the above studies continued unimpaired throughout the experiment.

REDUCTION OF THE PATHOGENICITY OF SEWAGE AND SEWAGE EFFLUENTS BY CHEMICAL COMPOUNDS.

The idea of sterilizing sewage and sewage effluents is not new. About thirty years ago the Rivers Pollution Commission of England was instrumental in setting on foot a movement looking to

the sterilization of sewagic matter. In 1900, in the Interim Report of the Royal Commission on Sewage Disposal of Great Britain, the statement is made that the commission was considering whether means were available whereby the destruction of such pathogenic bacteria as escaped in the effluents of artificial purification processes could be brought about in a practicable manner. The question was more exhaustively treated in their report for 1902, but led to no positive result other than a recommendation on the part of the commission that scientific studies be carried on to ascertain the extent of the danger of bacterial pollution against which their rivers should be protected.

The difficulty in bringing about the absolute sterilization of sewage obviously relates to the cost entailed by the use of an active and reliable germicide. Manganate of soda was used as a deodorant for a time in London, pending the opening of the precipitation works at that place. Permanganate of potash has been made use of for sterilizing purposes by the British army in India. Bleaching powder was used for sterilizing the water supply during the typhoid epidemic at Maidstone in 1897. Electrozone has proven under favorable conditions to be an efficient sterilizing agent, as has the more highly expensive peroxide of chlorine. During 1904, the efficiency of oxychloride as a germicide when applied to sewage effluents was demonstrated by Dr. Rideal,[10] who, as a result of his studies, stated that he found the process practical, effectual, and economical. The efficiency of ozone as a germicide when adequately applied to water is well known. Recently the value of metallic salts, such as copper sulphate and copper chloride, has received particular attention in this connection.

Copper chloride and copper sulphate, used for many years past by canning industries to prevent bacterial fermentation, have been experimented with by many investigators to determine their effect on pathogenic organisms. In 1904, in experiments of this character, presumably suggested by the revival on the part of the United States Department of Agriculture of questions relating to the efficiency of copper sulphate as a germicide, Rideal and Baines[11] showed that, when applied to flasks of boiled distilled water and flasks of filtered tap water, both of which had

been inoculated with *bacillus coli* and *bacillus typhosus*, respectively, copper sulphate in the proportion of 1 to 5 000 destroyed coli in one hour's contact, but not typhoid. Similarly, with copper chloride, 1 in 26 000 destroyed coli in three hours and typhoid in one hour. In concentration of 1 in 100 000, both coli and typhoid successfully resisted both copper sulphate and copper chloride for at least twenty hours, the maximum period over which the experiments were extended.

The results of the researches of Moore and Kellerman [12] in this connection are widely known. Their conclusions regarding the germicidal effect of copper sulphate upon *bacillus typhosus* are that "it should prove particularly useful in very large water supplies accidentally or suddenly contaminated with typhoid bacilli and not provided with any adequate means of purification." They further state that "in general, an epidemic could be controlled and quickly eradicated by a solution much weaker than 1 in 100 000, listed as necessary for complete sterilization, within twelve hours."

Soon after the work at the Columbus Sewage Testing Station was inaugurated, Bulletion No. 64 of the United States Department of Agriculture appeared, giving a *résumé* of the practical results obtained from the treatment of waters with copper sulphate for the elimination of algal growths. Incidental mention was also made of the indications that this chemical might have considerable value in the prevention of typhoid fever, through its application to polluted water supplies at times of typhoid fever epidemics. The subject appeared to be of sufficient importance to merit a study of the effect of copper sulphate when applied to sewage and sewage effluents, and the results of such studies made at the Columbus Testing Station, and the practical conclusions which it has been possible to draw therefrom are next presented.

AN OUTLINE OF THE STUDIES MADE AT THE COLUMBUS SEWAGE TESTING STATION ON THE EFFECT OF COPPER SULPHATE AS A GERMICIDE WHEN APPLIED TO SEWAGE AND SEWAGE EFFLUENTS.

Lack of time has prevented the working out of many highly desirable features in connection with the subject at hand, but

some points of practical significance have been brought out in our work, the substance of which is now presented. The work was aimed particularly at the following questions:

1. Rapidity of the germicidal action of copper sulphate.
   (*a*) The effect of temperature.
   (*b*) The effect of organic matter.
   (*c*) The effect of carbonates dissolved in the sewage.
2. Amounts of copper sulphate required:
   (*a*) For the reduction of total numbers of bacteria.
   (*b*) For the destruction of bacteria in feces.
   (*c*) For the destruction of *bacillus coli*.
   (*d*) For the destruction of *bacillus typhosus*.

The manner of conducting the experiments may be briefly described as follows:

The effect of the copper sulphate treatment was studied in connection with crude sewage, the effluents of certain coarse-grain beds, the effluents of sand filters, fresh feces diluted with sterilized distilled water, and with sterilized distilled water inoculated with pure cultures of *bacillus typhosus*.

All tests were made in volumes of at least 100 cubic centimeters, and the copper sulphate was added in the form of an aqueous solution, freshly prepared for each test. The chemical was ordinary commercial copper sulphate ($CuSO_4 + 5H_2O$), and was found on analysis to be 95 per cent. pure. Except where otherwise stated, the test flasks were kept at a constant temperature of 20° C. The culture media employed in the work were prepared in strict accordance with the methods recommended by the Committee on Standard Methods, 1905.[13] The numbers of bacteria were determined after incubation of the gelatine plate cultures for forty-eight hours at 20° C. In the tests to show the reduction in numbers of *bacillus coli* and *bacillus typhosus*, strict determinative differentiating tests were employed in all cases, that no doubt might remain regarding the identity of these organisms before and after the copper sulphate treatment. These tests were carried out in the manner described by the Committee on Standard Methods, 1905.

The results presented below represent in each instance the averages of from three to five separate series of tests. It may be

of interest to record the fact that no startlingly radical differences were noted in the results of the individual tests.

Acknowledgment here is due and gratefully made to Mr. W. R. Copeland and Mr. C. B. Hoover for the important part which they took in the studies outlined above. A preliminary report of the results of these experiments was presented at the Havana meeting of the American Public Health Association.[14]

THE EFFECT OF COPPER SULPHATE ON THE BACTERIAL CONTENT OF SEWAGE AND SEWAGE EFFLUENTS.

The results presented in Tables Nos. 1, 2, 3, and 4 show that when used in the proportion of 1 to 1 000, the germicidal action of the chemical continues uninterruptedly for twenty-four hours. Apparently the chemical must be added in quantities in excess of 1 part in 10 000 to prevent the bacteria from increasing in numbers after a period of contact of about six hours.

EFFECT OF ORGANIC MATTER AND DISSOLVED CARBONATES ON THE GERMICIDAL POWER OF COPPER SULPHATE IN SEWAGE AND SEWAGE EFFLUENTS.

In the tests designed to show the effect of organic matter and alkalinity on the germicidal power of copper sulphate in sewage and sewage effluents, crude sewage and the respective effluents of a sprinkling filter and a sand filter were used. The flask cultures were prepared in triplicate, namely, undiluted, and diluted one to one and one to two parts of distilled water, respectively.

The results presented in Tables Nos. 5, 6, and 7 indicate that while there appears to be a fairly well-defined tendency for the germicidal power to increase as the amount of organic matter is diminished, within the limits of our tests the differences thus shown were too slight to be of practical significance.

EFFECT OF TEMPERATURE ON THE GERMICIDAL POWER OF COPPER SULPHATE.

The results presented in Table No. 8 bring out forcibly the effect which low temperatures have in slowing down the germi-

cidal action of copper sulphate. In a general way, irrespective of the amount of chemical used, $2\frac{1}{2}$ times as many bacteria were destroyed after one-half hour in the flasks set at 20° C. as in the flasks set at 5° C.; 15 times as many after two hours, and 20 times as many after six hours. At the end of eighteen hours the numbers of bacteria in the flasks containing the lowest amount of chemical had increased to a point where further comparison of this character was made impossible. There were no such increases noted in the flasks kept at the low temperature.

EFFECT OF COPPER SULPHATE ON THE BACTERIAL CONTENT OF FECES.

In this test 5 grams of fresh feces were diluted with 1 500 cubic centimeters of sterilized distilled water. Two sets of flask cultures were prepared, one set being placed at a temperature of 5° C., and the other at 25° C. The control cultures showed the characteristic effect of temperature on the rate of multiplication of bacteria under such conditions, and the effect of temperature on the germicidal power of copper sulphate was again clearly brought out.

The rapidity of action of the chemical was normal. An interesting fact was brought out during this test, when it was shown that the control cultures contained no spore-forming bacteria. This fact effectually disposed of the suspicion that the bacteria which were able to withstand the high concentrations of the chemical, and even increase prodigiously in numbers after a time, might be enabled to do so by their spore-forming proclivities.

EFFECT OF COPPER SULPHATE ON BACILLUS COLI IN CRUDE SEWAGE AND SEWAGE EFFLUENTS.

In Tables Nos. 10, 11, and 12 are presented the results of tests to show the effect of copper sulphate on *bacillus coli* in sewage and in sewage effluents. As previously mentioned, all of the differential tests for *bacillus coli* were determinative.

The results show that when the chemical was applied to crude sewage in the proportion of 1 to 10 000, the coli were exterminated within one hour. In concentrations of 1 to 50 000, 200 *bacillus*

coli persisted for one hour; 10 for six hours; and all of the *bacillus coli* were dead at the end of twenty-four hours. In the culture flasks prepared from the effluent of a sprinkling filter, 10, 20, and 100 *bacillus coli* persisted for one hour in concentrations of one part of copper sulphate in 1 000, 5 000, and 50 000 parts of effluent, respectively. Tests made at the end of six hours showed all of the *bacillus coli* to be dead in all of the flasks. In the flasks prepared from the effluent of a sand filter, the coli were apparently all dead at the end of one hour in the flasks where the chemical was used in the proportion of 1 to 1 000. In those flasks where the concentrations were 1 in 10 000, 50 coli persisted for one hour, and one for six hours. All *bacillus coli* were dead at the end of twenty-four hours.

EFFECT OF COPPER SULPHATE ON BACILLUS TYPHOSUS.

The severest test of all, from the standpoint of the ability of the organism to resist the effect of the chemical, was applied in connection with studies designed to show the effect of copper sulphate on *bacillus typhosus*. Flasks in duplicate of sterilized water were inoculated with a culture of *bacillus typhosus*. One set of flasks was set at a temperature of 7° C., the other at 28° C. The typhoid cultures used were obtained from Parke, Davis & Co., and from the Ohio State University. The former culture was apparently fresh, while the latter was an old stock culture. Both were rejuvenated before use in accordance with the method recommended by the Committee on Standard Methods, 1905, and readily responded to the agglutination test when the experiment was begun.

At a temperature of 7° C., the control culture showed a reduction in the number of typhoid bacilli from 200 000 to 8 000, or about 96 per cent., in forty-eight hours. Small numbers of typhoid persisted in all of the treated flasks for forty-eight hours at this temperature. Concentrations ranging from 1 in 50 000 to 1 in 4 000 000 were used.

At a temperature of 28° C., 75 out of 200 000 typhoid persisted in a concentration of 1 in 50 000 for one hour, but all were apparently dead at the end of four hours. In a concentration of

1 in 100 000, 550 typhoid bacilli were alive at the end of one hour; 10 at the end of four hours; and 1 at the end of seven hours. The weaker concentrations showed a fairly consistent falling off in germicidal power as the amount of the chemical was decreased.

TABLE No. 1.

Copper Sulphate *vs.* Bacteria in Crude Sewage.

Initial Composition of Sewage.
- Organic Nitrogen, 6.3 parts per million.
- Alkalinity, 376 ,, ,, ,,
- Bacteria, 1 200 000 per cubic centimeter.

	Bacteria per c.c. Total Numbers.			
Hours of Contact.	0	1	6	24
$CuSO_4$ 0	1 200 000	1 200 000	6 000 000	14 000 000
,, 1 in 1 000	1 200 000	3 000	190	35
,, 1 ,, 10 000	1 200 000	9 500	250	200
,, 1 ,, 50 000	1 200 000	14 000	700	3 400 000

TABLE No. 2.

Copper Sulphate *vs.* Bacteria in the Effluent of a Sprinkling Filter.

Initial Composition of Effluent.
- Organic Nitrogen, 4.0 parts per million.
- Alkalinity, 290 ,, ,, ,,
- Bacteria, 1 000 000 per cubic centimeter.

Hours of Contact.		1	3	6	24
Average Number of Bacteria per Cubic Centimeter.	$CuSO_4$ 0	1 000 000	2 200 000	3 300 000	3 300 000
	,, 1 in 1 000	1 000	240	75	49
	,, 1 ,, 5 000	5 000	600	170	80
	,, 1 ,, 10 000	6 000	500	190	130
	,, 1 ,, 25 000	3 400	700	310	360 000
	,, 1 ,, 50 000	11 000	1 900	1 200	1 100 000
	,, 1 ,, 100 000	21 000	4 500	3 500	3 500 000

TABLE No. 3.

Copper Sulphate vs. Bacteria in the Effluent of a Contact Bed.

Initial Composition of Effluent. { Organic Nitrogen, 2.7 parts per million. Alkalinity, 320 " " " Bacteria, 400,000 per cubic centimeter.

Hours of Contact.		1	3	6	24
Average Number of Bacteria per Cubic Centimeter.	$CuSO_4$ 0	600 000	850 000	1 200 000	1 600 000
	" 1 in 1 000	430	60	40	30
	" 1 " 5 000	1 100	130	65	45
	" 1 " 10 000	2 100	230	100	250
	" 1 " 25 000	1 200	230	430	37 000
	" 1 " 50 000	3 500	600	1 100	65 000
	" 1 " 100 000	7 500	1 200	1 800	800 000

TABLE No. 4.

Copper Sulphate vs. Bacteria in the Effluent of an Intermittent Sand Filter.

Initial Composition of Effluent. { Organic Nitrogen, 0.87 parts per million. Alkalinity, 270 " " " Bacteria, 280 000 per cubic centimeter.

Hours of Contact.		1	3	6	24
Average Number of Bacteria per Cubic Centimeter.	$CuSO_4$ 0	310 000	410 000	440 000	700 000
	" 1 in 1 000	2 100	280	70	22
	" 1 " 5 000	6 000	1 400	350	40 000
	" 1 " 10 000	5 500	1 800	430	90 000
	" 1 " 25 000	6 500	1 300	800	100 000
	" 1 " 50 000	13 000	2 600	3 000	470 000
	" 1 " 100 000	20 000	5 000	5 500	450 000

TABLE No. 5.

COPPER SULPHATE *vs.* BACTERIA IN UNDILUTED AND DILUTED CRUDE SEWAGE.

(Tests for Numbers of Bacteria made at Start, and after 1 Hour's Contact.)

Parts of Dilution Water (H_2O).		0	1	2
Parts per Million.	Organic Nitrogen	8.9	4.4	3.0
	Alkalinity	400	200	133
Average Number of Bacteria per Cubic Centimeter.	Before adding $CuSO_4$	3 300 000	1 900 000	1 200 000
	$CuSO_4$ 1 in 1 000	2 300	1 600	950
	„ 1 „ 5 000	5 000	4 000	1 000
	„ 1 „ 10 000	12 000	9 000	2 200
	„ 1 „ 25 000	23 000	12 000	1 100
	„ 1 „ 50 000	68 000	30 000	8 000
	„ 1 „ 100 000	128 000	46 000	17 000
Average number in all treated flasks .		40 000	17 000	5 000
Percentage reduction		98.8	99.1	99.6

TABLE No. 6.

COPPER SULPHATE *vs.* BACTERIA IN THE UNDILUTED AND DILUTED EFFLUENT OF A SPRINKLING FILTER.

(Tests for Numbers of Bacteria made at Start, and after 1 Hour's Contact.)

Parts of Dilution Water (H_2O).		0	1	2
Parts per Million.	Organic Nitrogen	6.7	3.3	2.2
	Alkalinity	328	164	101
Average Number of Bacteria per Cubic Centimeter.	Before adding $CuSO_4$	550 000	300 000	170 000
	$CuSO_4$ 1 in 1 000	850	500	400
	„ 1 „ 5 000	3 700	1 800	500
	„ 1 „ 10 000	6 000	3 800	1 900
	„ 1 „ 25 000	5 500	3 100	1 200
	„ 1 „ 50 000	8 500	3 900	2 100
	„ 1 „ 100 000	15 000	3 000	1 600
Average number in all treated flasks .		6 600	2 700	1 300
Percentage reduction		98.8	99.1	99.2

TABLE No. 7.

Copper Sulphate *vs.* Bacteria in the Undiluted and Diluted Effluent of an Intermittent Sand Filter.

(Tests for Numbers of Bacteria made at Start, and after 1 Hour's Contact.)

Parts of Dilution Water (H_2O)		0	1	2
Parts per Million.	Organic Nitrogen	1.62	0.81	0.54
	Alkalinity	360	180	120
Average Number of Bacteria per Cubic Centimeter.	Before adding $CuSO_4$	200 000	130 000	100 000
	$CuSO_4$ 1 in 1 000	5 500	3 300	2 700
	,, 1 ,, 5 000	18 000	18 000	2 100
	,, 1 ,, 10 000	12 000	5 000	1 200
	,, 1 ,, 25 000	18 000	6 500	2 000
	,, 1 ,, 50 000	48 000	15 000	6 000
	,, 1 ,, 100 000	60 000	19 000	9 000
Average number in all treated flasks .		26 900	11 100	3 800
Percentage reduction		87	91	96

TABLE No. 8.

Effect of Temperature on the Germicidal Power of Copper Sulphate in a Contact Bed Effluent.

Concentration of Copper Sulphate Employed.	Temperature at which Flasks were Kept during Test.	Bacteria per Cubic Centimeter. Period of Contact in Hours. 0	0 5	2	6	18
1 in 25 000	5° C.	490 000	37 000	24 000	5 500	1 300
	20	600 000	15 000	1 300	250	350
1 in 50 000	5	500 000	48 000	34 000	3 900	1 800
	20	600 000	18 000	2 900	650	3 900
1 in 100 000	5	460 000	100 000	50 000	24 000	2 600
	20	600 000	44 000	3 300	700	81 000
Percentage Reduction in Numbers.						
1 in 25 000	5	.....	92.5	95.1	98.9	99.7
	20	.....	97.5	99.7	99.9	99.9
1 in 50 000	5	.....	90.4	93.2	99.2	99.6
	20	.....	97.0	99.5	99.9	99.3*
1 in 100 000	5	.....	78.3	89.1	94.8	99.4
	20	.....	92.7	99.5	99.9	86.5*

* Note. — These figures are distorted by increases in the number of bacteria after the chemical lost its germicidal power.

TABLE No. 9.

Copper Sulphate *vs.* Fecal Bacteria.

(Five grams fresh feces in 1 500 c.c. sterilized distilled water.)

Bacteria per c.c.	Flasks Standing at 5° C.					Flasks Standing at 25° C.				
Hours Contact	0	1	3	6	28	0	1	3	6	28
$CuSO_4$ 0	800	600	1 200	1 200	600	800	1 200	1 200	2 800	2 000 000
,, 1 in 50 000	800	600	360	270	21	800	25	2	0	5
,, 1 ,, 100 000	800	550	260	120	15	800	15	1	0	7 700
,, 1 ,, 250 000	800	500	500	400	35	800	50	15	2	13 000
,, 1 ,, 500 000	800	500	750	490	100	800	100	23	10	12 000
,, 1 ,, 1 000 000	800	1 200	500	330	70	800	100	38	25	17 000
,, 1 ,, 2 000 000	800	300	900	700	450	800	600	100	65	10 000
,, 1 ,, 4 000 000	800	800	700	700	550	800	600	450	500	110 000

TABLE No. 10.

Copper Sulphate *vs.* Bacillus Coli in Crude Sewage.

Initial Composition of Sewage.
- Organic Nitrogen, 6.3 parts per million.
- Alkalinity, 376 ,, ,, ,,
- Bacteria, 1 200 000 per cubic centimeter.
- B. coli communis, 10 000 per cubic centimeter.

Bacteria per c.c.	Total Numbers.				B. Coli.			
Hours Contact ..	0	1	6	24	0	1	6	24
$CuSO_4$ 0	1.2*	1 200 000	6 000 000	14 000 000	10 000	20 000	40 000	40 000
,, 1 in 1 000	1.2*	3 000	190	35	10 000	0	0	0
,, 1 ,, 10 000	1.2*	9 500	250	200	10 000	0	0	0
,, 1 ,, 50 000	1.2*	14 000	700	3 400 000	10 000	200	10	0

* Note. — Million.

TABLE No. 11.

Copper Sulphate *vs.* Bacillus Coli in the Effluent of a Sprinkling Filter.

Initial Composition of Effluent.
- Organic Nitrogen, 2.0 parts per million.
- Alkalinity, 248 ,, ,, ,,
- Bacteria, 300 000 per cubic centimeter.
- B. coli communis, 2 000 per cubic centimeter.

Bacteria per c.c.	Total Number.				B. Coli.			
Hours of Contact ..	0	1	6	24	0	1	6	24
$CuSO_4$ 0	300 000	380 000	750 000	300 000	2 000	2 000	5 000	10 000
,, 1 in 1 000	300 000	150	65	80	2 000	10	0	0
,, 1 ,, 10 000	300 000	2 500	125	300	2 000	20	0	0
,, 1 ,, 50 000	300 000	95 000	500	200 000	2 000	100	0	0

TABLE No. 12.

COPPER SULPHATE *vs.* BACILLUS COLI IN THE EFFLUENT OF AN INTERMITTENT SAND FILTER.

Initial Composition of Effluent.
- Organic Nitrogen, 0.46 parts per million.
- Alkalinity 240 „ „ „
- Bacteria, 29 000 per cubic centimeter.
- B. coli communis, 1 000 per cubic centimeter.

Bacteria per c.c.	Total Numbers.				B. Coli.			
Hours of Contact ..	0	1	6	24	0	1	6	24
$CuSO_4$ 0	29 000	40 000	45 000	270 000	1 000	1 000	3 000	5 000
„ 1 in 1 000	29 000	50	3	6	1 000	0	0	0
„ 1 „ 10 000	29 000	100	10	50	1 000	50	1	0
„ 1 „ 100 000	29 000	200	10	3 500	....	....	....	....

TABLE No. 13.

COPPER SULPHATE *vs.* BACILLUS TYPHOSUS.

(Flasks of sterilized water, H_2O, inoculated with rejuvenated culture of *bacillus typhosus*. Number of typhoid at start, 200 000 per cubic centimeter.)

Hours of Contact.	Flasks Standing at 7° C.				Flasks Standing at 28° C.			
	1	4	7	48	1	4	7	48
$CuSO_4$ 0	150 000	50 000	50 000	8 000	290 000	178 000	140 000	220 000
„ 1– 50 000	21 000	3 100	700	2	75	0	0	0
„ 1–100 000	25 000	2 400	700	4	550	10	1	0
„ 1–500 000	21 000	1 600	900	3	800	15	3	0
„ 1–1 000 000	19 000	1 800	500	65	1 500	50	7	0
„ 1–2 000 000	32 000	10 000	12 600	120	11 000	150	10	1
„ 1–4 000 000	92 000	63 000	31 000	5 500	6 000	60	15	4

BRIEF DISCUSSION OF THE TABLES.

Except for the purpose of making the data as complete as possible, the effect of copper sulphate on the total numbers of bacteria in sewage and sewage effluents has but little direct bearing on the matter at hand. As shown by the results presented above, there are some forms of bacterial life which are able to resist the action of copper sulphate for days, and for some or all of these forms, in cases where less than 1 part of the chemical in 10 000 parts of sewage or sewage effluent is used, copper sulphate loses

its germicidal power after about six hours, and from that time on these forms continue to rapidly increase in numbers. So far as is known, and judging from the results of our tests, these resisting forms are non-pathogenic.

The deleterious effect of organic matter and dissolved carbonates on the germicidal power of copper sulphate has not been clearly brought out in our tests. They are doubtless somewhat of a factor, but within practical limits, judging from the results presented above, they cannot be considered as materially disturbing elements.

The effect of temperature is the most important physical feature among factors which have to do with the germicidal power of this chemical. The significance of this fact is immediately apparent when it is recalled that it is frequently during the cool weather that the elimination of the typhoid bacillus is the most urgently desired. During extreme cold weather, when the water approaches the state of maximum density, the action of copper sulphate as a germicide is very slow, relatively speaking, and the results presented in Table No. 13 show that a comparatively large number of typhoid bacilli resisted the action of this chemical, when used in the proportion of 1 in 50 000 for a period of seven hours. Attention is here called to the fact indicated by the results in Table No. 13, that at a low temperature concentrations of 1 in 1 000 000 will effect on typhoid practically the same result as would a concentration of 1 in 50 000; but that lower concentrations than 1 in 1 000 000 give markedly inferior results. At the warmer temperatures the same thing is true in a measure, although there is a sharper gradation in the germicidal power of the chemical as the concentrations are increased. Where the storage facilities were adequate to permit of a period of contact of several hours, as weak a concentration as 1 in 1 000 000 would be practically as effective as one twenty times as great so far as killing the great majority of the typhoid germs is concerned.

As to the effect of copper sulphate on *bacillus coli* in sewage and sewage effluents, it seems reasonable to assume that, within limits, the points established in connection with this organism may be applied with a considerable degree of directness to the typhoid bacillus. It was deemed to be impracticable to attempt

a study of the effect of the chemical upon the typhoid bacillus in unsterilized sewage and sewage effluents, and *bacillus coli* was studied in its stead. All of these tests were made at a comparatively high temperature, 20° C., and the results showed that, generally speaking, a considerable number of these organisms could and did resist the germicidal effect of the chemical for something like six hours or more, in both sewage and sewage effluents, when as high a concentration of the copper sulphate as 1 in 50 000 was employed.

COST OF COPPER SULPHATE.

In Table No. 14 there are listed the various concentrations employed in the tests above described, giving also corresponding figures to show the amounts of the chemical in grains per gallon, pounds per million gallons, and cost for chemical per million gallons. In these figures only the bare cost of the chemical is given, no allowance being made for the cost of devices for its application, or for supervision and attendance charges.

TABLE No. 14.

COST OF COPPER SULPHATE PER MILLION GALLONS.

Concentration.	Grains per Gallon.	Pounds per Million Gallons.	Cost for Chemical per Million Gallons @ $0.06 per Pound.
1 in 1 000	58.500	8 357.1	$501.43
1 ,, 5 000	11.700	1 671.4	100.29
1 ,, 10 000	5.850	835.7	50.14
1 ,, 25 000	2.340	334.3	20.06
1 ,, 50 000	1.170	167.1	10.03
1 ,, 100 000	0.585	83.6	5.01
1 ,, 250 000	0.234	33.4	2.01
1 ,, 500 000	0.117	16.7	1.00
1 ,, 750 000	0.078	11.1	0.67
1 ,, 1 000 000	0.058	8.4	0.50
1 ,, 2 000 000	0.029	4.2	0.25
1 ,, 3 000 000	0.019	2.8	0.17
1 ,, 4 000 000	0.014	2.1	0.13
1 ,, 5 000 000	0.012	1.7	0.10

SUMMARY AND CONCLUSIONS.

The evidence seems to be reasonably sound that certain types of the typhoid bacillus, possessing special powers of resistance,

may successfully evade not only natural destruction when found outside the human body, but also almost all reasonable attempts toward their extermination by the use of copper sulphate when applied within practicable limits of economy on a large scale. These especially hardy types constitute perhaps but a small fraction of all typhoid bacilli, but even so, they are a specific menace to the public health.

There is ample evidence on record to prove beyond peradventure that, through natural causes, the vast majority of typhoid germs die out fairly quickly in sewage and running water into which they find their way. The data are quite as conclusive that artificial purification of sewage by fine-grained filters will result in a substantial elimination of such organisms. That complete sterilization of sewage effluents and polluted water may be effected by chemical means is also an indisputable fact, but the difficulty and cost entailed by their entirely successful use are decided drawbacks to their practical application.

With increasing knowledge of the difficulties and expense of hygienically treating at sewage works the entire water-carried wastes of a city, the more practical and important becomes the plan of thoroughly disinfecting all dejecta before they leave the sick room. Here it can be done effectively at small cost.

While the effluents of all artificial processes may perhaps be properly regarded as "potentially dangerous," the effluent of a process where sand filtration at low rates is employed for the purification of sewage is undoubtedly the most desirable hygienically of all the known processes which have been practiced to date. The treatment of sewage on sand filters, however, is very expensive for some localities, particularly where the material for the sand beds must be transported from a distance. In some places its cost would be prohibitive. Sewage treatment in coarse-grain filters is apparently much less expensive under ordinary conditions. The effluent of such works is decidedly inferior hygienically to that obtainable from sand filters. It does not seem improbable, therefore, that in some localities a place of usefulness will be found for copper sulphate, in reducing the pathogenicity of coarse-grain filter effluents to a point where they will be comparable with those from sand filters.

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Experiments upon the Removal of Microscopic Organisms from Ponds and Reservoirs by the Use of Copper Sulphate.

BY X. H. GOODNOUGH.*

The possibility of the removal of microscopic organisms from the waters of ponds and reservoirs by the use of copper sulphate was brought to the attention of the State Board of Health of Massachusetts by Dr. George T. Moore some three years ago, and experiments upon this method of improving the water of reservoirs affected by such growths were begun under my direction in the year 1903. The work has been carried on by Mr. Henry E. Mead, an assistant engineer of the State Board of Health, and during the past two years five ponds and reservoirs have been treated with copper sulphate, some of them several times, and the results observed. In addition, the results of the application of copper sulphate to two other ponds and reservoirs by persons not connected with the State Board of Health have been noted.

The application of the copper sulphate was made in the earlier cases under the advice of Dr. Moore and under the immediate

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direction of his assistants, Messrs. Kellerman and Robinson, and in the later cases by Mr. Mead, who has followed the methods in which he was instructed.

It is impossible to do more in the time reasonably allowable for a discussion of the papers presented than to give an outline of these experiments and refer briefly to the results.

The sources which have been used for experiment are the Belchertown reservoir in the town of Belchertown, Mass., used formerly as a source of public water supply by the city of Springfield, and the Arlington, Lexington, and Quincy storage reservoirs, and Jamaica Pond, formerly used as sources of water supply by portions of the Metropolitan district near Boston. The biological and chemical characteristics of most of these waters were very well known, as a result of frequent examinations of their waters covering periods, in most cases, of many years. Fewer examinations had been made of the water of Belchertown reservoir before the experiments were begun than of any of the others, but enough was known to show that this reservoir was affected annually by the presence in the summer season of great numbers of the organism *Anabæna*.

BELCHERTOWN RESERVOIR.

Belchertown reservoir was originally constructed for mill purposes many years before it was used as a source of water supply. Its area is about 35 acres, its general depth from 4 to 5 feet when full to the level of the overflow, the maximum depth being 7 feet, and it holds when full about 56 000 000 gallons. The bottom is of mud, and the drainage area of about 3.2 square miles contains large areas of swamp. Over much of the area of the reservoir the water is ordinarily covered with growths of *chara*, pond lilies, and water weeds of various sorts. The reservoir contains the fish common to this region. The water is highly colored and contains practically at all times a large quantity of organic matter.

This reservoir was first treated with copper sulphate on July 21, 1904, in a quantity amounting to 1 part of copper sulphate to 8 000 000 parts of water, *Anabæna* having appeared earlier in the month and increased until the filaments numbered 1 200 per cubic centimeter. There were also other organisms

present in the water, about ten different kinds being noted, but the numbers of each were small. The copper was applied at the Belchertown reservoir and also in all of the other cases by placing it in gunny sacks and trailing it through the water at the stern of a boat until the copper became thoroughly dissolved, effort being made to reach all parts of the reservoir.

After the application of the copper to Belchertown reservoir on July 21, 1904, the numbers of *Anabæna* decreased rapidly, and the organism had practically disappeared within six days, though occasionally one or two were found in subsequent samples up to August 18. The numbers of other organisms present in this water also rapidly decreased after the copper was applied, until on the twenty-seventh day of July, within six days after the treatment, they numbered about 370 per cubic centimeter; but from this point they increased with great rapidity to nearly 4 000 per cubic centimeter toward the end of August, and subsequently to nearly 5 000 per cubic centimeter in September. The numbers then gradually fell off with the approach of winter.

The organisms which grew most abundantly after the disappearance of the *Anabæna* were *Asterionella* and *Tabellaria*, and but very few other organisms of any kind were present. At the time of this first treatment three fish — suckers — were found dead in the reservoir. Some doubt was expressed as to whether these fish were killed by the copper.

In 1905, *Anabæna* appeared in Belchertown reservoir much earlier than in the previous year, and by the middle of May the numbers had become excessive. The treatment of the reservoir was delayed until June 13, when copper was applied in a quantity amounting to 1 part in 8 000 000 parts water, the same as in the previous year. After this treatment the numbers of *Anabæna* decreased somewhat, but early in July they began to multiply again and the reservoir was again treated, on July 18, with the same quantity of copper sulphate, 1 part in 8 000 000 parts of water. After this treatment the numbers of *Anabæna* gradually diminished, and none have been found since August 4.

After the disappearance of the *Anabæna*, *Scenedesmus* appeared in large numbers, but at the time of the most recent available examination — August 29 — while the number of genera repre-

sented was much larger than usual, the number of organisms was much smaller than in the previous year, amounting to less than 1 000 per cubic centimeter. No dead fish were found after either of the treatments in 1905, nor did the fish appear to be visibly affected.

The quantity of copper present in the water of the reservoir was found to vary greatly at different times, and some of the samples contained a much greater quantity of copper than the quantity applied, indicating an uneven distribution of the copper in the water at different times. The reservoir is very shallow, as already stated, and the water becomes greatly agitated at times of high winds.

ARLINGTON RESERVOIR.

Arlington reservoir has an area of 29.2 acres at the level of the overflow and holds about 66 000 000 gallons. It is shallow, the maximum depth being about 9 feet, and the general depth not over 7 feet. The watershed at present has an area of about 1.1 square miles. The water is highly colored and contains usually a very large quantity of organic matter. The reservoir has been subject to growths of *Anabæna,* which have sometimes appeared in enormous numbers, but it is not affected by *Anabæna* in every year. It has, however, contained other organic growths which have made the water very objectionable for water supply purposes.

Copper sulphate was applied to the reservoir four times in the years 1903 and 1904. The first application of copper sulphate to this reservoir was made August 5, 1903, and this was the first of the experiments made by the State Board of Health upon the use of copper in clearing reservoirs from organic growths. At the end of June, 1903, the total number of organisms in the reservoir numbered nearly 13 000 per cubic centimeter, consisting chiefly of *Scenedesmus, Synedra,* and *Asterionella.* The numbers decreased during July to a minimum of about 4 000 by the first of August, and then began to increase again, and on August 5 numbered about 5 000 per cubic centimeter, consisting almost wholly of *Scenedesmus.* The quantity of copper sulphate applied was 1 part in 1 500 000 parts of water. After the copper was applied

the number of organisms increased for a day or two and then diminished. They then rapidly increased to a maximum of somewhat more than 8 000 per cubic centimeter, chiefly *Scenedesmus.* Toward the latter part of August they again increased to a maximum of nearly 12 000, *Scenedesmus* continuing to be the principal organism present.

Organisms reappeared in May, 1904, in numbers running up to 18 000 per cubic centimeter, consisting chiefly of *Synedra* and *Scenedesmus*, the organism which was most prominent in the previous year, but after the culmination of this growth in the latter part of May, the number of organisms decreased rapidly until about the middle of June, when the number present had fallen to about 1 000 per cubic centimeter. At this point a growth of *Staurastrum* appeared, and the number of organisms again increased to nearly 9 000 per cubic centimeter by the latter part of June, diminishing by the middle of July to about 1 500, and then rapidly increasing again toward the end of the month to about 6 000, the organisms present being almost a pure culture of *Staurastrum.*

On July 28, copper was again applied in a quantity amounting to 1 part in 3 700 000 parts of water. The growth of organisms decreased for a day or two, but subsequently increased until August 8, when the number had risen to 9 000 per cubic centimeter, still almost wholly *Staurastrum.*

On August 10, copper was again applied in a quantity amounting to 1 part in 700 000 parts of water. The organisms then decreased rapidly for a week, and the *Staurastrum* very soon disappeared almost entirely, but was rapidly replaced by a growth of *Protococcus* and *Scenedesmus* and other organisms until a total of 9 500 was reached near the end of August, when copper sulphate was applied a fourth time on August 30, in a quantity amounting to 1 part in 700 000 parts of water. The organisms then diminished rapidly from 9 500 to about 3 000 in the early part of September. The growth then increased rapidly to more than 11 000 by the middle of October, and remained high until the early part of November, when it gradually diminished as cold weather approached. No fish were killed by the first two treatments of 1 part of copper in 1 500 000 parts of water on

August 5, 1903, or 1 part in 3 700 000 parts of water on July 28, 1904, but the application of copper in a quantity equivalent to 1 part in 700 000 parts of water on August 10, 1904, caused the death of about fifty white perch about six inches in length, but no other dead fish were found, and even while these fish were floating in the water, boys were catching similar fish on the shores of the reservoir. No fish were apparently affected by the application of copper amounting to 1 part in 700 000 parts of water on August 30, notwithstanding the very large quantity of copper which still remained in the reservoir from previous treatments.

Determinations of the quantity of copper present show that it remained in the water of the reservoir in large quantity, though it gradually diminished. The quantity of copper sulphate applied in the three treatments in 1904 amounted to about 1 part in 300 000. On January 9, 1905, the quantity present in the water was 1 part in 7 100 000 parts of water. On June 23, 1905, the quantity of copper found in the water was 1 part in 21 000 000. Microscopical examinations in 1905 show that enormous organic growths still continue in this reservoir. *Synedra* appeared in great numbers early in May, rising to 23 000 per cubic centimeter toward the end of the month, nearly a pure culture of this organism. *Staurastrum* and *Scenedesmus* appeared in July, and *Anabæna* appeared for the first time in this reservoir for several years in August, rising to 176 per cubic centimeter on September 1. The general condition of the reservoir water has been very objectionable both during and since the experiments.

LEXINGTON RESERVOIR.

Lexington reservoir has an area of about five acres and a storage capacity of about eight million gallons. Its depth is about eight feet, and its bottom contains but little mud and organic matter. Soon after its construction in 1893 its water was affected by a considerable number of organisms, chiefly of the smaller kinds, but frequently by the *Infusoria* which have made the water at times objectionable on account of taste and odor. Two experiments have been made in the application of copper sulphate in this reservoir, the first being on February 28, 1905, when the quantity applied was 1 part in 1 000 000 parts of water.

The copper was applied in the usual burlap sacks through a single hole in the ice, the object of applying the copper in this way being to observe its diffusion in the water. Samples were taken before and after treatment at four different points in the reservoir, and at different depths at each point. The results of this test show that the copper settled to the bottom of the reservoir beneath the hole through which it was applied and remained there, spreading but little until the breaking up of the ice on April 4. After the breaking up of the ice, the copper quickly diffused throughout the water of the reservoir, and during April was equally distributed in all portions of it from which samples were taken. In June large quantities of *Uroglena* appeared in the reservoir at a time when the quantity of copper still present in the water amounted to 1 part in 25 000 000 parts of water. Copper was then applied at the rate of 1 part in 20 000 000 parts of water, and on the next day, July 1, the average quantity of copper present in the water was 1 part in 12 000 000 parts of water. The *Uroglena* disappeared in about a week and did not again appear. On July 25 the quantity of copper remaining in the water had diminished to 1 part in 32 000 000.

QUINCY RESERVOIR.

This reservoir has an area of 45 acres and holds when full about 170 000 000 gallons of water. The maximum depth is about 27 feet, and the bottom contains considerable mud and organic matter. The reservoir is made up of two widely separated arms which join at the dam. A large brook flows into the upper end of one of the arms and this stream is the main feeder of the reservoir; the other arm occupies a narrow crooked valley with a very small watershed, and receives no considerable amount of water. The reservoir was built in 1887 as a source of water supply, but its use has been discontinued. The water is considerably colored and contains in the summer season large quantities of organic matter, and frequently numbers of organisms, *Diatomaceæ* being the most abundant, though blue-greens sometimes have been present in large numbers; green algæ and occasionally *Infusoria* have been fairly numerous.

Only one experiment has been made at this reservoir, and the

object in this case was to study the diffusion of copper sulphate. On March 7, 1905, when the reservoir was covered with a foot or more of ice, copper was applied in a quantity amounting to 1 part in 1 000 000 parts of water. All of the copper was applied at the upper end of the arm which receives the main feeder of the reservoir, and all of it was dissolved through a single hole in the ice. Previous to the treatment, samples were taken at nine sampling stations, three in each arm, and three running across the reservoir parallel to the dam and 250 feet from it. Samples were taken frequently until April 7, at which time the ice had disappeared from the reservoir. It was found that the copper settled to the bottom as soon as applied, and while the ice remained moved very slowly toward the dam. No copper appeared in the other arm of the reservoir until after the breaking up of the ice.

The samples collected immediately after the ice disappeared show that the copper had become evenly diffused throughout both arms and all parts of the reservoir. Subsequently, after the stratification of the water in May, the copper appeared to concentrate in the lower layers, though considerable quantities of it still remained in the upper layers of the reservoir.

The watershed of this reservoir is about one thousand acres, and much of the copper was carried out of the reservoir at the time the ice broke up by the freshet flow from the watershed.

JAMAICA POND.

Jamaica Pond is a natural pond, and was the original source of water supply of a portion of the city of Boston. Its use was continued up to 1892. Its area is about seventy acres and it holds about six hundred million gallons of water. It is very deep, with steep shores for the most part, though there is one shallow cove. The maximum depth of the pond is about fifty feet. The watershed is small in proportion to the capacity of the pond, and the water changes very slowly. Under ordinary conditions the water is nearly clear and colorless.

This pond has been affected for many years by enormous growths of the organism *Oscillaria*, which, however, have not appeared in every year, but usually in every other year. The organism appeared in great numbers in the year 1903, and copper

sulphate was applied on September 23 of that year. The quantity applied in this case was 1 part in 1 500 000 parts of water, and in this case a small amount of lime was added three days after the treatment. The *Oscillaria* gradually disappeared from the water and did not appear in 1904.

In the year 1905 the organism again appeared in great numbers, and copper sulphate was applied on August 19 in a quantity amounting to 1 part in 2 000 000 parts of water. The application of the copper took several hours, and it was noticed that fish began to be affected about three hours after the treatment began, and within the week following it is estimated that from 4 000 to 6 000 fish died as a result of the treatment. The fish represented nearly all of the kinds present in the pond, including, it is said, some of the eels. Many of the fish were taken for examination, and all the specimens, with one exception, were found to be females.

The examinations show that the numbers of *Oscillaria* are diminishing and the pond is clearing somewhat, but the results of this test are not yet available.

Samples were collected to determine the quantity of copper present in the pond both before and after treatment. Before treatment, copper was found in quantities ranging from 1 part in about 50 000 000 at the surface to 1 part in 127 000 000 in the bottom water. The copper was applied, as is already stated, on August 19. On August 21 samples were taken at two different places in the pond and at various depths, the results showing that in two samples collected at the surface the quantity was one part in 1.1 millions and one part in 1.4 millions. At a depth of 15 feet the quantities were one part in 4.1 millions and one part in 3 millions, respectively, at the two stations. At a depth of 30 feet the quantity of copper at both stations was 1 part in 32 000 000 parts of water, and at a depth of 45 feet the quantity of copper at one station was 1 part in 47 000 000. The sample from the other station was lost in transit.

Thus it appears that two days after the treatment the copper was concentrated mainly in the upper layers of the pond. The water of this pond becomes markedly stratified in the summer

season, the temperature at the bottom remaining in the neighborhood of 50° F., while the temperature of the surface water rises to that found in other ponds in this region.

Two other tests of the application of copper by persons not connected with the State Board of Health have been made, the results of which have been noted. In Crystal Lake in Newton, a small pond situated in a densely populated residential district, but not used as a source of water supply, *Anabæna* appeared in great numbers early in August, and on August 18 copper sulphate was applied to the water in a quantity amounting to 1 part in 4 000 000 parts of water.

In this instance also a number of fish died, and analyses of samples of water collected on September 1, two weeks after the treatment, showed that the copper remained very largely in the upper layers of the pond, while very little was present in the water nearer the bottom. The *Anabæna* diminished slowly at first and then quite rapidly, until on September 26 the numbers had become insignificant. Other organisms, however, grew rapidly as the *Anabæna* diminished, *Scenedesmus* appearing in very large numbers in the latter part of September. In this pond, as in Jamaica Pond, a great variation in the temperature was noted between the surface and bottom waters, though the depth of the pond is much less than that of Jamaica Pond.

Massapoag Lake in Sharon has an area of about three hundred and fifty acres and is used as a source of ice supply, but not for water supply. The ice company, in order to rid the pond of an excessive growth of *Anabæna*, which is said to have injured the quality of the ice, applied copper sulphate to the water of the lake in October, 1904, in a quantity amounting to 1 part in 5 000 000 parts of water. Subsequent to this treatment the fish died in great numbers, and it is estimated that 250 000 fish of all kinds and sizes were found dead upon the shores of this lake within a short time after the application of the copper sulphate.

SUMMARY.

Summarizing a few of the more notable results of these experiments, it is found that in Belchertown reservoir the copper sul-

phate quickly destroyed the *Anabæna* the first time it was applied at the rate of 1 part in 8 000 000 parts of water. *Anabæna* appeared in the following year much earlier than usual and were not destroyed by an application of the same quanity of copper as in the previous year, but were destroyed by a second application of this quantity. The organisms decreased in numbers much less rapidly than at the time copper was applied in the previous year. After the *Anabæna* had disappeared when copper sulphate was first applied (in 1904), other organisms quickly grew in great numbers. Whether this will be true in the present year remains to be seen.

At Arlington the treatment of the water with copper sulphate even in large quantities had very little effect upon the number of organisms contained in the water, and the condition of this reservoir as regards the presence of organisms was not in any way improved by the application of the copper.

At Jamaica Pond the application of copper sulphate in 1903 destroyed the *Oscillaria* and they did not appear in 1904, though as stated, this organism rarely appears in large numbers in two succeeding years. The *Oscillaria* appeared again in great numbers, however, in 1905, and the numbers have thus far diminished slowly.

Very great differences were found in the effect of the copper upon the fish in the different reservoirs, and great differences in the action of the copper upon the fish in the same reservoir at different times. Practically no fish were killed in the treatment of any of the storage reservoirs — Belchertown, Lexington, Quincy, or Arlington — except that in the latter a small number were killed upon the application of quantities of copper in excess of the amounts usually deemed necessary for the destruction of *Anabæna* and similar organisms. On the other hand, in all of the natural ponds treated, Jamaica Pond, Massapoag Lake, and Crystal Lake, fish were killed, in some cases in enormous numbers. The application of 1 part of copper in 2 000 000 parts of water in Jamaica Pond in August of the present year resulted in the death of many fish, though no fish at all were killed by the application of copper sulphate in September, 1903. The application of copper sulphate to Crystal Lake in an amount equal to one

half the quantity applied at Jamaica Pond about the same date caused the death of numbers of fish, while the application of only 1 part of copper in 5 000 000 parts of water to Massapoag Lake resulted in the death of many thousand. Many of the fish killed in Massapoag Lake and Jamaica Pond were of large size, black bass from four to five pounds in weight being among the victims.

The great differences in the diffusion of copper in water under different conditions are also remarkable. Deposited in a pond under the ice, it sank to the bottom and diffused but slowly until after the breaking up of the ice, but when the ice broke up and the water was completely turned over by the winds in the early spring, the diffusion was complete.

At Belchertown reservoir the copper was found to be highly concentrated in some of the samples. Recent observations upon the application of copper to Jamaica Pond and Crystal Lake show that its diffusion in the summer also may be very slow under some conditions, and that the copper may become highly concentrated in the upper layers of the water.

The results of these experiments show in general that copper sulphate when applied to the water of a pond or reservoir does not in many cases diffuse evenly, and that there is danger that when this substance is applied to waters of ponds or reservoirs used as sources of water supply much stronger solutions of this substance, which is regarded as poisonous even in very small quantities, may be delivered to consumers than is indicated by the ratio of the quantity applied to the total contents of the pond.

DISCUSSION.

MR. KARL F. KELLERMAN.* I have very little to say, Mr. President, and I do not want to interfere with what other men who are to participate in this discussion are more able to bring before you than I am. There is one point, however, which I think probably might not be dwelt upon, which seems to me to deserve especial attention, and that is the character of the water that is to be treated. I think the water itself deserves considerable study before the application of the copper can be made to

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the best advantage. As Dr. Moore said to you at the beginning, referring to the susceptibility of different fish, we recognize that brook trout is probably the most sensitive fish, yet a few years ago one of the gentlemen connected with the Bureau of Fisheries told me of some experiments he had been carrying on in Wisconsin, and there, with water that is exceptionally hard and contains a rather unusually low amount of free carbonic acid, he was able to add a quantity of copper nearly a hundred times as great as that species of fish can ordinarily endure. I think this indicates that before a water can be treated successfully for algal growths, and before it is possible to treat it with safety to the fish, it is necessary not only to know the organism for which you are going to treat, but also the character of the water with which you are to deal.

I think this point is emphasized to some extent by the discrepancies between the papers of Mr. Ellms and of Mr. Clark, Mr. Ellms reporting the precipitation of the copper within twenty-four to forty-eight hours, depending on the character of the water, chiefly the organic matter contained. In Mr. Ellms' report it is stated, I believe, that the organic matter, even when he had rather a high quantity, was able to delay precipitation only about twenty-four hours, while Mr. Clark has just told you that in his experiments precipitation was sometimes delayed for more than twenty days.

New England water must be considered, therefore, more or less in a class by itself, because so far as our experience has gone, the reports of the western chemists are unanimous, I think, as to the comparatively rapid precipitation of the copper. We have only a few figures on eastern waters, and those of Mr. Clark are far and away the most extreme as to the length of time of the copper remaining in solution. If popular prejudice or scientific demand requires the study of the final disposition of the copper, or requires its complete elimination from the water, further research and perhaps additional processes will have to be inaugurated.

MR. EARLE B. PHELPS.* One of the most interesting observations of Dr. Moore and of Prof. Kraemer is the germicidal

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effect of metallic copper upon typhoid infected water with which the copper may come in contact; and the suggestion has been made that the use of copper utensils, water-tanks, pitchers, and drinking goblets, might be of some service in protecting us against infection. The United States Geological Survey, through the Division of Hydro-Economics, has been carrrying out some studies upon the subject of the copper canteen, as to its availability for general army use and for use among the field parties of that bureau, and these investigations have been placed in my hands. Perhaps the results, so far as they are available, may be of interest at this time.

It is obviously impossible to use clean scoured copper canteens, and Professor Kraemer found it necessary, and other workers have always found it necessary, to keep their copper plates clean and scoured. I have attempted in my experiments to imitate as far as possible perfectly natural conditions, and I think none of us would consider cleaning with acid a feasible thing in the field or in the army. I started with clean copper canteens, cleaned with oxalic acid and very thoroughly rinsed. From that time on the canteens were not treated in any way, but they were allowed to accumulate any coating or tarnish which might form. The first series of experiments was made with Boston tap water, and following out the idea of using natural conditions I did not sterilize or filter the water, but took it just as it came from the tap. Of course I had to use large numbers of the typhoid germs in order to detect them with certainty at the conclusion of the experiment. The detection of the typhoid organisms was in every case checked up at the end of the experiment by the Widal test, which, of course, is the only sure criterion for the surviving germs.

Starting with the clean canteen and Boston tap water, the amount of copper dissolved in the first experiment was about two parts per million. In succeeding experiments the amount fell off, and at the eighth successive test it had reached a point less than a half of one part per million.

The efficiency of the canteen in destroying typhoid was considerable at the start, although nowise complete. I used large numbers of the organisms, about 100 000 per cubic centimeter, as nearly as I could hit it by dilution, and the final tests were

generally made at the end of twenty-four hours. At first the numbers were in the neighborhood of 6 to 10 per cubic centimeter. At the end of the series of experiments, or so far as we have gone with them, the numbers are in the neighborhood of 30 or 40, sometimes more. In only one case was there complete elimination of the typhoid organisms, and if I am not mistaken, the copper at that time amounted to about one part per million. It was after the fifth successive test.

Aside from the work with the Boston tap water, I have carried out similar experiments upon other waters, for I agree with the previous speaker that the quality or the chemical characteristic of the water is the essential factor. I have used both hard waters and turbid waters, and find that in both cases the efficiency is very much lessened. Calcium salts seemed to be especially harmful, and calcium carbonate the worst of all; the efficiency of the canteen upon a water high in calcium carbonate was almost nothing. Turbid waters also interfered seriously with the effect of the copper canteen upon the typhoid organisms. Mr. Sullivan of the Geological Survey, in attempting to explain the formation of copper deposits, has suggested a very interesting theoretical consideration in this connection. That is, that there is a law of chemistry, the so-called *mass law*, which demands that kaolin or common clay shall precipitate out the copper as silicate, a corresponding amount of alkaline salt being formed and dissolved.

I have also carried out a series of experiments on Boston tap water, using canteens which had been in use with these hard western waters, and found that the efficiency of the canteens was permanently lost and could not be recovered without carefully cleaning the canteen again. That is as far as I have gone. I have used three strains of typhoid organisms in attempting to find some relation between the age of the organism and the efficiency of the canteen upon it, but so far the differences are too slight to notice. The three strains had been on artificial media about two years, one year, and one month, respectively, and, as I say, the differences in the effect upon the three strains were not noticeable.

MR. ROBERT S. WESTON.* Many bodies of water which are not used as sources of water supply, but which are used for pleasure, ornament, or for furnishing ice, often suffer from disagreeable growths of odoriferous algæ. This has been especially noted in New England, because of the prolonged drought during the present summer. Many of the lakes and ponds which ordinarily are inoffensive have produced such enormous growths of *Anabæna* and other organisms as to be exceedingly offensive to the inhabitants of their shores.

Such was the case at Newton Centre, Mass., where the waters of Crystal Lake were so offensive during August as in many cases to cause the dwellers on the shores of the lake to move away. An examination of the water on August 11 showed it to be very turbid with a growth of *Anabæna*. These organisms produced the usual objectionable "pigpen" odor.

In a report to Mr. H. A. Stone, secretary of the Newton Board of Health, the writer advised the treatment of the reservoir with copper sulphate in the proportion of one part of the chemical to four million of the water. This procedure was carried out under the direction of Mr. Stone, with the coöperation of the city engineer, Mr. I. T. Farnham.

The lake, which has an area of 31 acres and a capacity of about 142 650 000 gallons, was divided into seventy sections, and each section was treated separately with its proportionate weight of chemical. Allowance was made for the variation in depth of the pond.

The chemical, contained in sacks, was applied in the customary way by trailing it astern of a boat. Two sacks were used alternately, the one in use being kept more than two thirds full at all times.

The chemical was applied on Friday, August 18. An improvement in the appearance of the water was noticeable in three hours. After two days the water contained about 25 per cent. as many *Anabæna* as before treatment. On the 21st the improvement was very marked, and on the following Wednesday, the 23d, the water was of excellent appearance and free from odor, in which condition it has remained until the present date, September 9. The pond contains an abundance of bass and perch,

*Sanitary Expert, Boston, Mass.

none of which were killed by the treatment. The only fish killed were about a peck of small fingerlings or minnows. The cost of the treatment was less than fifty dollars.

While it is true, as Mr. Goodnough states, that there was a growth of *Scenedesmus* after the application of the copper sulphate, this organism was unobjectionable, while the odoriferous *Anabæna* were destroyed.

It would seem, therefore, that from the above experience copper sulphate has a field of usefulness in similar cases where a nuisance is to be avoided. This treatment should be conducted with extreme care, as inefficient distribution of the chemical will certainly cause the death of many fish. The writer does not believe that the use of strong concentrations of copper sulphate is feasible in such cases, as it is extremely unwise to destroy all the objectionable organisms in a pond if at the same time large numbers of fish must be killed, as has been the experience in other cases.

The writer hopes for an opportunity to apply copper solution in the form of a spray, using for this purpose such an atomizer as is used for spraying trees and crops. The better the distribution, the greater the concentration which can be applied without destroying the fish.

In conclusion, the writer may say that he believes copper sulphate to be an efficient tool in proper hands, but not one which can be put to all sorts of uses.

Dr. George A. Soper.* The copper sulphate method has been advanced as a means of putting an immediate check to typhoid epidemics due to infected water supplies, and it is this point to which I will restrict my discussion. The official statement of Messrs. Moore and Kellerman, to which I refer,† is contained in one of the last bulletins of the Department of Agriculture, and is as follows:

"Treatment with copper sulphate is an effective and practicable means of sterilizing water polluted with certain pathogenic bacteria, and as an emergency method is applicable to both household and municipal conditions. It should prove particu-

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* Consulting Sanitary Engineer, New York City.

† Bulletin No. 76, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905, pp. 38–39.

larly useful in very large water supplies accidentally or suddenly contaminated with typhoid bacilli and not provided with any adequate means of purification. Under such circumstances the case becomes not one of pure water versus water containing copper sulphate, but of sterile water containing an amount of copper not dangerous to health versus water and typhoid bacilli. The method formerly suggested for treating a reservoir would undoubtedly be advisable in special cases of unusually great contamination when the water contained an abnormal amount of organic matter, but *in general an epidemic could be controlled and quickly eradicated by a solution much weaker than the 1 to 100 000* listed as necessary for complete sterilization within twelve hours. *One to 2 000 000 is sufficient in most cases*, and even less than this quantity of copper is of decided benefit in certain kinds of water." (Italics mine.)

The experiments which have been made with copper sulphate in the destruction of typhoid fever germs have been made in the laboratory under conditions which should show the very best results for the copper sulphate treatment, yet there appears to be a good deal of uncertainty as to the amount necessary in order to destroy the germs. For a disinfectant to be reliable, we must know with accuracy how much to apply in order that all of the dangerous bacteria may be destroyed. As has been well pointed out, it will not do to dose the public water supply with chemicals in the mere hope of doing some good. By disinfection we seek to destroy all the offensive organisms, and when we attempt to disinfect a water supply, the public depends upon us to accomplish this result. Half-way measures in disinfection are not possible; the result must be absolute or it is misleading.

From experiments which have been mentioned here, and which have been paralleled by some which I had an opportunity to make at the College of Physicians and Surgeons in New York, about eighteen months ago, it appears that we are not by any means certain that all the typhoid fever germs in a water, even in a laboratory, will be destroyed by one part of copper sulphate in 75 000; and yet that dose, if applied to the filtered Croton water, will produce such an opalescent appearance and blue color that people will not drink it.

The technique of the laboratory experiments which have been

reported seems to me to afford incomplete evidence that typhoid fever germs will be destroyed even in a concentration of copper sulphate as high as 1 part in 25 000. In 1902, Schüder* published a critical study of various methods which had been proposed for sterilizing water by means of chemicals, and in this he reviewed the results of experiments of other investigators. Schüder found that the common plate method did not afford certain evidence of disinfection; that there were apt to be germs left over from the process or surviving in a feeble condition on the plates which he could find by a more delicate process. His improved procedure was in substance as follows: After allowing the disinfectant to act for the time which was thought to be sufficient for sterilization, the excess of disinfection was neutralized, and enough soda added to the water to produce an ordinary alkaline reaction. The entire sample of water, amounting to many hundred cubic centimeters, was then divided up into flasks of 100 to 200 cubic centimeters each, and to each of these was added enough concentrated peptone salt solution to form a 1 per cent. peptone salt culture medium. The flasks were then incubated for thirty-seven hours at 37° C. They were finally examined for typhoid bacilli by means of the Conradi Dreglaski method and the colonies so developed were fished and tested by the agglutination test. Schüder's conclusion was that results obtained in any less delicate way were certain to be unreliable and misleading.

There is another consideration which indicates that the laboratory experiments, even granting that they have been accurate, which I think they have not, will not apply with any certainty to conditions of actual practice. Most, if not all, of the experiments have been made with typhoid germs which have been cultivated in bouillon. The organisms so cultivated are certain to be evenly distributed through the water and sterilized. This is not a condition known to exist in nature. It is not likely that the typhoid bacilli which produce an epidemic in a water supply are separated evenly throughout the water. It is far more reasonable to believe that they are usually aggregated in clumps or small masses of feces and other matter. This being so, the copper sulphate would have to penetrate those masses in order to be

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* Zeit. f. Hyg., 1902, xxxix, p. 379.

effective in destroying the germs. There have been no experiments made which indicate that copper sulphate has any efficiency in this particular direction.

Two opportunities have occurred in my practice to use a chemical disinfectant to sterilize a water supply in order to check an epidemic. One was at Ithaca, N. Y.; this was an epidemic, it will be remembered, of about thirteen hundred cases. I had been called on to act as expert by the New York State Department of Health to do what was possible to stop the progress of the disease. It was proposed by L. M. Dennis, professor of chemistry at Cornell University, that a chemical be applied to the water in the hope of sterilizing not only the water but the distribution pipes of the water works and the reservoir. The disinfectant proposed was permanganate of potash. The amount required was carefully estimated from experiments made in the laboratory and the proposer of the process spent much pains in order to secure a sufficient supply of pure chemical for use. It was intended that the permanganate should be added in a solution at the pumps or reservoir and that the hydrants and faucets throughout the city should be allowed to run open until the characteristic pink color of the permanganate should appear. The arguments on both sides of the question were very carefully gone over by Professor Dennis and myself, and after considering the matter fully, I concluded that it was not desirable to attempt disinfecting the water supply in this way, but before taking the responsibility of deciding against an attempt, which, if successful, would have been so beneficent, I asked my friends, Messrs. George W. Fuller and Allen Hazen, who happened to be at Ithaca at that time, to confer on the subject. We met with Professor Dennis, the subject was fully discussed, and the disinfection of the water supply was thought by them to be an unwise and unpromising project to attempt.

Again at Watertown, N. Y., in 1905, where I acted as consulting sanitary expert to the city board of health in its efforts to suppress a typhoid epidemic of about six hundred cases, the use of a disinfectant to sterilize the water supply was carefully considered. The preliminary notices of the supposed value of copper sulphate were being published in the press while the epidemic was in progress, and I was urged by many persons to give it a

trial. I decided against the use of copper sulphate in this instance as being uncertain, untried, experimental, and unwarranted in view of the possibilities for mischief and misconception which it seemed to contain.

It is not necessary for me to go into the technical details which led me to reject the use of copper sulphate on two such important occasions. It can readily be appreciated, I think, by the members of this association that in order to reach every part of the material to be disinfected, it would be necessary to apply the disinfectant in very large quantities at first and that there would be extreme difficulty in making certain that it would penetrate to the various parts of the distribution system wherein bacteria might lurk. Too little is known about the behavior of the typhoid bacillus in the piping system of the water supply. We do not know the part played by bacteria in dead ends, among sediments and accumulations of organic matter such as exist in all water works, and there is need of more scientific information concerning the longevity of the germ in reservoirs.

It seems not improbable that the infectious matter which produces the great spring epidemics, which are the severest we have, is usually taken into the water works system at one time, perhaps within an hour or even a few minutes, and that it gains a lodgment there, developing and multiplying and giving off bacilli to the water which runs through the pipes for many weeks, if not months. In such epidemics as those of Butler, Ithaca, and Watertown, it usually is from ten days to three weeks from the freshet in the creek or river, when the germs are taken into the distribution system, before many cases of typhoid fever among the consumers of the water are discovered. It is usually between three and six weeks afterward that the maximum number of cases per day occur. It is usually betweeen two and three and one-half months before the disease ceases to be epidemic. There is no doubt that, even after these epidemics, cases of genuine typhoid have been contracted from the water supply. Theoretically, the supplies should have been emptied of their original water and refilled with fresh water by the natural process of supply and consumption within two or three days. It would seem inconceivable that this and the process of flushing the mains which was used in these

cases should not have removed all of the organisms. Yet against this reason the germs seem to have persisted.

To check an epidemic coming from a water supply by the use of chemical disinfectants applied to the water as it enters the pipes would require an exceedingly efficient process, far more so, I think, than has been demonstrated so far for the copper sulphate treatment. We know nothing whatsoever as to the certainty of the behavior of copper sulphate under the conditions of actual practice.

Mr. Allen Hazen.* The general discussion has been so excellent and has brought out so many points that I do not feel that I can add to it. I wish to mention only an historical point.

I think that the idea of using copper sulphate for destroying algæ in public water supplies is entirely due to Dr. Moore, and that he should receive all credit for it. But copper sulphate was suggested very seriously a long time ago in Germany for treating polluted water supplies. It was directly after the epidemic of cholera in Hamburg, in 1892, when exhaustive studies with different metallic salts were made by a German chemist, Kröhnke. This led him to recommend the use of copper sulphate in handling typhoid and cholera-infected water; but the German engineers, some of whom I knew at the time, were not willing to take the responsibility of giving their people copper in the quantity necessary to be effective in this way, and they thus anticipated that part of our present discussion.

Mr. George A. Johnson. I have only two points to which to refer, Mr. President. One of them has to do with Dr. Soper's remarks regarding the value of the experimental work which has been done in connection with these copper sulphate studies. It appears to me that their general value is very great, because in the laboratory conditions are kept under careful control, and such results as are obtained represent the extreme influence which this chemical can have on the specific organisms studied. Of course, as Dr. Soper has said, the results obtained by experimental work in the laboratory only have an indirect applicability to many practical propositions on a large scale.

* Consulting Engineer, New York City.

The other point to which I should like to refer has to do with the use of copper sulphate in connection with unfiltered water supplies. Experiments of such a nature were conducted by the Health Officer, Dr. McKendree Smith, at Columbus last year, and the results are set forth in a prominent manner in the last publications of Messrs. Moore and Kellerman. The conditions surrounding Dr. Smith's experiments were as follows:

The Scioto River, which serves as the source of a portion of the water supply of Columbus, is sometimes badly polluted. At the time of Dr. Smith's experiments it was at very low stage, being not much more than a succession of pools above the city. Copper sulphate was added intermittently to the Scioto water at or near the intake in quantities never in excess of one part in 1 500 000. The city of Columbus is on a direct pumping system, and, therefore, no very considerable period of time was possible for contact of the chemical with the water after its application. The longest period of contact which could have been obtained under any circumstances could not have amounted to more than about six hours.

There was one feature in connection with these experiments of Dr. Smith which as yet, I think, has never been brought out, and that has reference to the fact that the application of the copper sulphate to the river water was begun at the commencement of a prolonged drought of about four and one-half months, throughout which its use was intermittently continued, and then stopped by order of the city authorities some ten days after a succession of heavy rains. Almost immediately following the discontinuance of the chemical treatment the cases of typhoid fever began to increase. It has been claimed that the sudden outbreak of typhoid fever at this time was due to the fact that the copper sulphate treatment had been discontinued. From the following tabulated statement it appears to me that inasmuch as the treatment was intermittent at best and never extended to the entire city water supply, and as the chemical was never added in quantities in excess of one part in 1 500 000, and as a period of contact of only a few hours was possible, the increase in typhoid fever cases following the breaking of the drought was due to the flushing into the river and into the city mains of pol-

luting matter which had been accumulating for months, rather than to the discontinuance of the copper sulphate treatment. In other words, there is no sound evidence to show that there was much infection during the autumn for the copper sulphate to have destroyed, or that the treatment would have been as effective as claimed if it had been longer continued after the appearance of the belated fall rains.

RELATION BETWEEN THE NUMBER OF TYPHOID FEVER CASES IN COLUMBUS AND THE AMOUNT OF RAINFALL.

Month.	Number of Cases.	Total Precipitation for the Month. (Inches.)
June, 1904	24	2.78
July	23	2.27
August	52*	3.18
September	16	0.83
October	16	0.97
November	8	0.18
December	4	3.63†
January, 1905	91‡	1.25
February	376	1.57
March (to 27th)	279	1.87

MR. P. A. MAIGNEN.§ The question of sterilization of water by chemicals is not new. As far back as 1900, the speaker and Mr. Burlureaux, in Paris, found and published the fact that "hard" water, treated chemically for the elimination of the dissolved lime salts or "softened," was at the same time sterilized.

All chemical reactions in water interfere with the growth of bacteria. Almost any kind of chemical, added to the water in sufficient quantity, is capable of sterilizing.

We owe to Dr. Moore considerable credit for having brought to the front the question of the chemical sterilization of water and caused it to be taken into consideration, at a time when the chemical treatment of water in general, and with alum in particular, was under the ban of condemnation by the medical profession and the people generally.

* Copper sulphate used after August 19.

† Copper sulphate discontinued January 5.

‡ Between the dates December 24–27, 1904, the total rainfall amounted to 2.93 inches.

§ Filtration Engineer, Philadelphia, Pa.

We also owe to Dr. Kellerman a practical suggestion for the avoidance of the dangers presented by the chemical treatment of water. His suggestion amounts in effect to this, — that you may use any and all the chemicals you please, such as potassium permanganate or sulphate of copper (the latter being one of the strongest antiseptics known) in any quantity, provided you take care to remove all traces of chemical that might remain in the water after treatment. This removal can be obtained by secondary chemical reactions or by filtration through charcoal.

The speaker cannot help thinking that it is absurd to attempt to sterilize a whole lake or all the water supply of a large city. What is the use of sterilizing by copper, or otherwise, the water needed for elevators, gardens, laundries, boilers, street sprinkling, carriage washing, or putting out fires?

Absolute sterilization must necessarily be an expensive operation and should be confined to the water used for domestic purposes. In Paris there are two sets of water pipes, one set conveying spring and filtered water for domestic use, which is sold at twenty-four cents per thousand gallons, and another distributing plain river water intended for sprinkling and industrial purposes. The latter is sold at twelve cents per thousand gallons.

The speaker ventures to suggest the establishment, wherever practicable, of a double canalization; one to convey sterilized water for drinking purposes and another to supply plain water or water freed from mud by some economical system of filtration for industrial and municipal requirements. The speaker further desires to be understood as being favorable to the cause of chemical sterilization, provided it be carried out scientifically, economically, and with sufficient safeguards.

Mr. George C. Whipple.* After what has been said I feel that I have little to add to the discussion. My own experience in the practical use of copper has been limited. Perhaps I might mention one instance in my experience which is slightly different from what has been mentioned. The well of a certain farmer in New Hampshire had, for a number of years, been so bad that

* Consulting Engineer, New York City.

it could not be used, either for drinking or for watering the stock. The water was turbid, dark colored, and very offensive in odor. It had been so for a number of years, although several attempts had been made to clean out the well. Microscopical examination showed that the water contained a heavy growth of *Crenothrix manganifera*. I gave instructions to the farmer to dose this well with copper, let the water stand for several days, and then clean out the well thoroughly, washing off all the stones and removing all the sediment at the bottom. He followed my instructions and the treatment was entirely successful. After the well had been thoroughly pumped out the water became clear and sparkling and the supply is now perfectly satisfactory. I cannot state just how much copper was used, as I do not know just how much water there was in the well at the time when he made the application. The amount which I intended to use was one part in two million, and I think that this figure may be taken as approximately correct.

This case is interesting, as it shows the action of copper upon one of a group of microscopic organisms hitherto not experimented with to any extent.

Mr. Hazen has referred to the work which was done by Kröhnke a few years ago. Mr. Andrew Mayer, Jr., the chemist of our laboratory, has recently translated this paper, and as it contains many facts of interest I think that it will be well to incorporate his translation in this discussion in order that it may be available for convenient reference.

Mr. Mayer has also made in our laboratory a number of experiments upon certain details of the reactions which take place when copper is added to water. The effect of carbonic acid upon the solubility of the basic copper carbonate was one of the matters studied. It was found that the basic carbonate is soluble in carbonic acid free water to the extent of 0.4 parts per million, expressed as copper sulphate. The addition of carbonic acid increases the solubility of the basic carbonate very greatly, as shown by the following table:

Free Carbonic Acid. Parts per Million.	Solubility of Basic Copper Carbonate Expressed in Terms of Parts per Million of Copper Sulphate.
0	0.4
1	4
2	9
3	12
4	15
5	20
10	35
20	52
30	66
40	78
50	90
100	125

When both aluminum sulphate and copper sulphate were added to water, with enough sodium carbonate to take up all of the free carbonic acid formed by the reaction, it was found that copper sulphate was removed to the limit of solubility of the basic carbonate in water free of carbonic acid, namely, about 0.4 parts per million.

It was found further that different methods of preparing the basic copper carbonate gave different solubility results. In some cases the solubility in carbonic acid free water was as low as 0.2 parts per million.

Suggestions for the Improvement and Sterilization of Surface Water by Chemical Methods, with Special Reference to the Elbe Water at Hamburg.*

BY B. KRÖHNKE.†

[ABSTRACT.]

* * * * *

There yet remains, for the purpose of purification, chemical disinfection; and this method has the great advantage over filtration that it affects in the same way all portions of the water treated. The disinfecting medium must be sufficiently powerful to kill, with complete certainty, at least the pathogenic germs, in a

* In Journal für Gasbeleuchtung und Wasserversorgung, v. 36 (1893), p. 513.
† Translated by Andrew Mayer, Jr., chemist with Hazen & Whipple, New York.

reasonably short time, and also, if possible, all the other germs occurring in water, although this last condition is of less importance. There are, indeed, a large number of chemical reagents which fulfill this condition; a great number of them, however, are organic in nature, and although sufficiently powerful to completely kill all germs, even the best of them are open to the objection that they cannot be removed from the water again, economically or easily, and are thus out of the question for use with drinking water. It seems as though we were confined, for this purpose, to the inorganic poisons, and I have made a careful study of these, with reference to their use as disinfectants and with special reference to their easy and certain removal from water after their action has been completed. In looking over the inorganic compounds which could be used here, it seems to me that, in general, those elements are most poisonous for the living organism which have a great affinity for sulphur, and whose sulphides offer most resistance to decomposition by other compounds. There is really no absolute scale for the degree of toxicity of a substance. Poisons act in entirely different ways upon different organisms. There are, of course, a large number of elements and compounds which, by reason of their caustic qualities alone, act in a very poisonous manner and can destroy organic life, but for use here they are out of the question.

I confine myself entirely to those which are inimical to the inmost physiological life processes and can be considered septic or narcotic poisons. First in the scale of toxicity and of affinity for sulphur stand the alkali metals, which, in a strict sense, can hardly be considered poisonous. Their sulphides are easily soluble in water and are decomposed by very weak acids, even by carbonic acid. Then come the alkali earth metals, some of which are to a certain extent poisonous and whose sulphides are more insoluble than those mentioned above. Then come those metals whose sulphides are entirely insoluble in water and require fairly strong acids to effect decomposition. Noteworthy among these are iron, manganese, zinc, cobalt, nickel, etc. Finally comes that group of compounds whose sulphides are insoluble, not only in water, but also in diluted strong acids, that is to say, those acids which do not exercise any oxidizing action. To this group

belong, among others, bismuth, tin, antimony, arsenic, copper, silver, lead, mercury, etc., whose compounds are all poisonous, excepting only those which are absolutely insoluble in water, or in the juices of the living organism. Among all metals without exception, copper, when in the form of cuprous salts, for instance, cuprous chloride, stands first in affinity for sulphur. Copper in the form of cupric salts, on the contrary, has a much weaker affinity for sulphur and the corresponding sulphide is much less stable. Cupric chloride is also less poisonous than cuprous chloride. What relation this affinity for sulphur bears to the functions of life is another question. The albuminoids and the proteins probably play the leading parts in the living protoplasm, but concerning the chemical constitution of these bodies there is less known than of any other group in organic chemistry. Only this much is certain, they all contain sulphur as an essential constituent, but whether the copper, in the form of cuprous salt, produces decomposition by removing sulphur from the atomic complex of protein, and acts as a poison in this way, either directly or through the by-products formed, must remain for the present a very uncertain hypothesis. At any rate the apparent systematic parallel of the affinity of metals for sulphur on the one hand, and the degree of toxicity on the other, suggests the testing of cuprous chloride as a sterilizing medium, and the results apparently justify the above hypothesis. Cuprous chloride has also, for the purpose in question, still other valuable properties, viz., it can be very easily prepared, as I shall show later; it can be easily and certainly separated out again after use; its higher degree of toxicity disappears upon simple contact with the air by reason of its transformation into cupric chloride; the copper can be obtained again easily without loss; and, finally, it is not decomposed, like cupric chloride and the other cupric salts, by calcium bicarbonate, which is present in every surface water. For this very reason, apart from their slighter effectiveness as disinfecting media, the cupric compounds have less practical value for this work. They would have to be used in larger quantities, in order to act as desired, because they are, as has been stated, decomposed by the calcium bicarbonate present in water and thus precipitated and rendered ineffective.

Copper sulphate, it is true, is not immediately precipitated in the cold, but gradually, and in proportion as the carbon dioxide formed by the reaction escapes, for instance, through warming or through lessening of the air pressure. It is, however, gradually decomposed and changed to copper carbonate, which remains partially dissolved in the free carbonic acid for some time, so that even after twenty-four hours traces of copper can be found in the filtered water, even after the solution has become colorless. Cupric chloride, however, is more quickly decomposed by calcium bicarbonate than is the sulphate, and when the latter comes into contact with sodium chloride, which is always present in surface water, cupric chloride is formed by double decomposition. In order to avoid the decomposition of cupric chloride, the entire lime content of a water must previously be neutralized by sulphuric acid, or some other similar reagent, for instance, ferrous sulphate, or, better, by both combined, as the basic ferric sulphate which precipitates carries down part of the sulphur trioxide of the ferrous sulphate. In fact, by the addition of 1.2 gm. of concentrated sulphuric acid (1.83 specific gravity), 0.6 gm. copper sulphate and 0.6 gm. ferrous sulphate to 10 liters of water, I obtained, after the mixture had stood eighteen hours, a water completely free from germs, which developed no colonies of bacteria on nutrient gelatine after standing six days at room temperature. Upon subsequently adding 0.7 gm. of quicklime the water was rendered completely neutral and colorless and also free from copper, iron, and arsenic. The precipitate formed, when air dried, weighed 2.95 gm. or almost 3 kilograms per cubic meter of water. Cuprous chloride, however, is even more effective than cupric chloride or copper sulphate, is not decomposed by calcium bicarbonate as are the cupric salts, and, although soluble with difficulty in water, is still sufficiently so for action upon germs. When added in small quantities to surface water containing lime the mixture is almost absolutely clear, and the filtrate therefrom, even when diluted a million times, still shows a reaction for copper with potassium ferro-cyanide as well as with hydrogen sulphide. A very slight turbidity occurs after a considerable time, as a result of oxidation by the air contained in the water.

Cuprous chloride dissolves very readily, to the extent of about

36%, in hot, concentrated sodium chloride solution, but separates out again, upon cooling, in the form of small white crystals, leaving still in solution from 4 to 7 per cent. according to the temperature. Upon the addition of pure water, free from air, the larger part is thrown out as a heavy white crystalline precipitate; if, however, the water contains air, or organic matter, or if it has absorbed oxygen from the air and is, at the same time, neutral, containing no free acid, the cuprous chloride is at first retained in varying amount. Then there forms, gradually, a white precipitate which, after a short time, however, changes color and becomes a Pomeranian yellow. The presence of a little free acid, in the absence of organic matter, prevents this change in color. An entirely neutral solution of cuprous chloride in sodium chloride absorbs oxygen when exposed to the air, forming a green surface film of oxy-chloride with simultaneous formation of cupric chloride; if free acid is present this color is at first brown, which, upon continued action of the air, becomes a pure green. On account of this action of air upon cuprous chloride one must avoid as much as possible any strong agitation when mixing it with water, and must effect solution as rapidly as possibly by simple rotation. If this precaution is observed, especially with dilute solutions, only a very small portion remains directly in contact with air, and there is obtained a neutral cuprous chloride solution oxidized only by the air already contained in the water. This oxidation proceeds very gradually in the cold; not rapidly, as is the case with ammoniacal solution of cuprous oxide. That portion of the cuprous chloride which is thus oxidized reacts with any calcium bicarbonate present, and is gradually thrown down as a light blue-green precipitate of basic copper carbonate.

For the experiments on killing germs and the disinfection of Elbe water, I used a solution of cuprous chloride in sodium chloride, which, for convenience in calculation, contained almost exactly 1 per cent. metallic copper. In order to keep this solution entirely clear and colorless, it is necessary to render it slightly acid with a few drops of hydrochloric or sulphuric acid and place in it a coil of copper wire, or some strips of copper foil. The flask containing the solution should be immediately stoppered after using. Every time the flask is opened a little copper is dissolved as a

result of oxidation by the air admitted. For very precise experiments it is, therefore, necessary to frequently analyze the solution, to control the amount of copper used, or the necessary amount of solution must be drawn off and its volume replaced by carbon dioxide, or some other indifferent gas. I added 7.2 gm. of such a solution, which contained exactly 1.08 per cent. of metallic copper, hence .078 gm. of copper to 12 liters of Elbe water. This is in the proportion of one part of copper to 155 000 parts of water. I divided the mixture among 12 flasks which contained one liter each, and let them stand loosely covered, in order to prevent, as far, as possible, the entrance of germs from the air. The solution was at first absolutely clear. Later there appeared a very slight opalescence. Portions, when taken out and filtered until clear, slightly acidified, and mixed with potassium ferrocyanide, showed a rose-red color in thick layers, proving that copper was yet in solution, and this reaction persisted even after standing six days. The test for copper with ammonia, on the contrary, gave no result. After standing fifteen hours several portions were withdrawn, with the usual precautions, and plated out on gelatine. Several portions of the plain Elbe water, from which the mixture had been made, were also plated at the same time for comparison. I feared that the very slight trace of copper still in solution might prevent the development of the germs present when the mixture was plated out on nutrient gelatine, although in all probability the copper would be rendered insoluble by the alkaline reaction of the gelatine. Accordingly I added, to one flask of the mixture, clear lime water (containing 1-800 of its weight in lime) until a filtered portion gave no further reaction for copper. According to calculation, and taking into account the slight acid reaction of the cuprous chloride solution, one half as much lime as the copper added, that is, .04 gm. of lime or 32 gm. of lime water, should be sufficient for 12 liters of the mixture. The test portions, when filtered, still contained copper, however, even after the addition of 64 gm. or 96 gm. of lime water, but were completely free from copper after the addition of 120 gm. of lime water, which corresponds to one part of lime per 80 000 parts of water. The excess over the calculated amount is caused by the calcium bicarbonate present. After the precipitate formed,

upon the addition of the lime water, had settled out, 1 cc. was taken and plated out. Even after five days those plates made from the mixture, and also those made from the mixture to which lime had been added, still remained sterile, except for some isolated colonies, for the most part mould-growths, which should be considered as due to unavoidable errors of method. On the contrary, the control tests with the original Elbe water showed, after two days, 12 500 germs per cubic centimeter. In earlier experiments I obtained as much as 100 000 germs; the present (Jan. 18) marked decrease is due to the extreme cold and the freezing of the upper Elbe. Cultures plated from the mixture after it had stood twenty-four and thirty-six hours, respectively, were also sterile.

The filtered water obtained after treatment with lime was entirely colorless, completely free from copper and iron, neutral, and had, as all agree, a very good flavor, without the peculiar flat taste of Elbe water which has been boiled and then filtered. The precipitate containing copper, obtained from the entire 12 liters, weighed when air-dried .14 gm.; when dissolved and titrated in ammoniacal solution with potassium cyanide, it showed exactly the same amount of copper as had been added. Besides this, it contained the inorganic settlings and a considerable amount of organic matter which had been coagulated and precipitated with the copper. It contained, however, no carbonate of calcium. As was to be expected, such a slight precipitate settles very slowly from so much liquid, so that the water did not become sufficiently clear until it had stood somewhat longer than twenty-four hours. The precipitation is, however, much hastened by the addition of a little ferrous sulphate, in proportion of 1-50 000, before adding the lime. The amount of lime added must be correspondingly increased from 1-80 000 to 1-50 000. The better the precipitate coagulates the quicker the water clears; after repeating the operation several times and saving the precipitate, the further addition of ferrous sulphate would be no longer necessary.

* * * * *

The procedure for the purification of water with or without the addition of sulphide would be carried out in the following way: The water to be purified is drawn into a basin and stirred so rapidly that it will completely mix with the cuprous chloride without

absorbing too much oxygen from the air. The stirring might be done by a central mixer made of wood and copper. It should contain no iron. Then the cuprous chloride solution is allowed to flow in gradually and after it has been thoroughly mixed with the water, the mixture is allowed to rest 6 to 24 hours, as desired. The length of time necessary for this stage of the process depends upon the relative amount of cuprous chloride used, and is also governed by the extent of purification desired. If one is satisfied to leave a few harmless water bacteria, after killing all the pathogenic germs, one part of copper, in the form of cuprous chloride, per 1 000 000 parts of water, with a digestion of twenty-four hours, will be sufficient. This is in the proportion of one kilogram of copper per 1 000 cubic meters of water. It should also be remembered that after the settling of the precipitate the water is filtered and the small number of germs remaining still further reduced. If, however, it is desired to completely destroy all the germs in a water, five times as much copper must be used, or one kilogram of copper per 200 cubic meters of water, if the latter is of medium quality.

The water thus disinfected is run into a second basin and the separation of the copper is completed here. For this purpose there should be added the necessary amount of the mixture of iron sulphide and lime. The liquid should be then thoroughly agitated until a test portion shows that all the copper has been precipitated. One hour will be required, as a rule. The water should then be allowed to stand until sufficiently clear.

If it is desired, however, to remove the copper by the method first described, these reagents should be added in the following order:

1. Sodium sulphide (or calcium sulphide, or barium sulphide), either dissolved or as a powder.
2. Ferrous sulphate, dissolved in previously disinfected water.
3. Quicklime, either as lumps, which can be placed in a cage of iron and submerged in the water, or as milk of lime.

The mixture should then be strongly stirred from two to three hours and allowed to stand until the precipitate formed has settled and the clear water can be drawn off. The first settling will take place somewhat slowly and require at least twenty-four hours.

Later, however, when more precipitate is present, considerably less time will be required. The water, when drawn off gradually and at a sufficient distance from the bottom, contains none of the precipitate and is then ready for use. It is clear, neutral and free from copper and arsenic, even though the sulphuric acid used for dissolving the copper contained arsenic.

* * * * *

Objection will be made to the use of copper in water purification, since its compounds are more or less poisonous for men and animals. I shall accordingly endeavor to settle any doubt on this subject. Many substances in large doses act as poisons, but do not exert such effect in very dilute solutions. We daily consume with our food more or less matter which in large amount would act as poison. For instance, copper is normally found in the human body, even to an extent of 2 gm. Copper in the proportion of one part to one million of water as used for disinfection is equivalent to 1 gm. per cubic meter. This is only one half of the amount which the human body may already contain. During the process of disinfection, however, at least $\frac{9}{10}$ of this is rendered insoluble and separated out. There remains dissolved, therefore, per cubic meter of water, only $\frac{1}{10}$ gm. of copper. This is the maximum residual amount, and, at that, does not exist in the more poisonous form of cuprous chloride, but in the form of cupric chloride, as a result of oxidation by the air. Even if there were no further treatment with sodium sulphide, ferrous sulphate and lime, one would have to drink 20 cu. m., or 20 000 liters of water in order to take in as much copper as is already present in the system. At the rate of two liters per day this would require ten thousand days, or almost thirty years. The presence of even such a small amount of copper in the water, after treatment, is assumed only for the sake of argument, to overcome any prejudice which the public may have against this use of copper. As a matter of fact, the presence of copper would be absolutely impossible, even if the above precautions, that is, treatment with sodium sulphide, etc., were only partially observed. The danger to life and health from a far more dangerous cause, viz., the bacteria of water, merits much more earnest attention.

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TABLE A. TYPHOID BACILLI (1 cc. used for plating).

Mixture made with Cu_2Cl_2 sol. containing 1% Cu.	After Addition of Cu_2Cl_2.			After Precipitation.		From the Precipitate.
	7 hours.	12 hours.	23 hours.	24 hours.	48 hours.	
I. 1 000 cc. water 3 cc. Cu_2Cl_2 Dilution 1–333 333	10 colonies 4 gray liquefiers No typhoid	5 colonies 2 gray liquefiers No typhoid	3 colonies 2 gray liquefiers No typhoid	7 colonies 1 Wurzel bacillus 1 gray liquefier No typhoid	2 colonies No typhoid	About 200 colonies. Many Wurzel bacilli. Majority liquefiers, some gray No typhoid
II. 1 000 cc. water 2.5 cc. Cu_2Cl_2 Dilution 1–100 000	8 colonies 2 gray liquefiers 2 Wurzel bacilli No typhoid	5 colonies 1 Wurzel bacillus No typhoid	8 colonies 3 gray liquefiers 3 Wurzel bacilli 2 surface non-motile No typhoid	40 colonies 2 surface No typhoid	Sterile	Like I
III. 1 000 cc. water 2.22 cc. Cu_2Cl_2 Dilution 1–450 000	3 colonies 1 Wurzel bacillus 1 gray liquefier No typhoid	7 colonies 2 Wurzel bacilli 2 round 2 gray liquefiers 1 yellow No typhoid	2 colonies 1 Wurzel bacillus 1 light liquefier No typhoid	Sterile	2 colonies No typhoid	Like I
IV. 1 000 cc. water 2 cc. Cu_2Cl_2 Dilution 1–500 000	7 colonies 3 gray liquefiers No typhoid	5 colonies 1 Wurzel bacillus 1 gray liquefier No typhoid	4 colonies 1 Wurzel bacillus No typhoid	25 colonies 10 gray liquefiers 2 surface No typhoid	About 1 000 colonies Majority liquefiers No typhoid	Liquefied
V. 1 000 cc. water 1 cc. Cu_2Cl_2 Dilution 1–1 000 000	8 colonies 3 gray liquefiers 1 round No typhoid	11 colonies 2 Wurzel bacilli 5 surface, which did not grow like typhoid No typhoid	8 colonies 1 Wurzel bacillus No typhoid	60 colonies 30 gray liquefiers No typhoid	Countless colonies Many liquefiers No typhoid	Liquefied

TABLE B. CHOLERA BACILLI.

500 cc. sterilized distilled water added to	Plated with 1 cc. water, after period of 6 hours.	12 hours.	24 hours.	48 hours.	Remarks.
I. 10 cc. cholera culture in 1% Pepton solution + 0.5 cc. 1% Cu_2Cl_2 solution 1-100 000	Many cholera colonies visible after two days standing	Sterile	Sterile	Sterile	After the addition of the Cu_2Cl_2 solution the water assumed a blue color, because it was rendered alkaline by the Pepton solution. The color was discharged by 1 drop H_2SO_4
II. 3 cc. aqueous emulsion of cholera culture + 0.33 cc. 1% Cu_2Cl_2 solution 1-150 000	Isolated cholera colonies appeared in four days. The movement of the bacilli, as seen in hanging drop, was very feeble	Sterile	Sterile	Sterile	
III. 3 cc. aqueous emulsion of cholera culture + 0.25 cc. Cu_2Cl_2 solution 1-200 000	Many colonies after standing three days	Sterile	Sterile	Sterile	
IV. 3 cc. aqueous emulsion of cholera culture + 0.2 cc. Cu_2Cl_2 solution 1-250 000	Sterile	Sterile	Sterile	Sterile	

MR. H. W. CLARK. I just want to mention one or two things in regard to the methods used for the determination of copper, which were suggested by what Dr. Kellerman said about the Massachusetts results being different from others, in the time taken for sedimentation of copper, etc. I think we really ought to have a standard method for the determination of copper in water. I have not seen in the published reports of the amount of copper found in the various western reservoirs after treatment any statement as to the way the copper present was determined. The general method of determining copper is by the potassium ferro-cyanide test, which is only delicate enough to show a part

of copper in about two million parts of water,—that is, distilled water. If you have a natural water which is colored with iron and organic matter, the color given by the test is very much disguised, even when copper is present in the amount just stated. The method we have evolved at the laboratories of the State Board of Health in Boston, and which has been adopted by the Committee on Standard Methods of Water Analysis of the American Public Health Association, is quite different from that. It is a long and rather tedious method, perhaps, but we can determine copper accurately when it is present in water in very minute amounts. It is simply a question of patience and having water enough and evaporating it down, getting rid of the iron and organic matter and silicates present, and then depositing the copper by electrolysis on platinum dishes. It is easy to work and accurate. I think if that method was more generally in vogue we should know more about the sedimentation of copper in some of these western reservoirs which have been treated. In saying that I do not mean to cast any reflection on the ability of the various chemists who have tested the water in those reservoirs, but I imagine they haven't used a delicate enough method for determining copper.

PROF. HERBERT E. SMITH. I have already used my quota of time, but I will take a moment, if I may, to refer briefly to a couple of cases which have come within my observation. These are a little interesting, because they were cases of a considerable growth of *Uroglena* in reservoirs which are not commonly affected by other troublesome growths. They both occurred during the early part of the present year, in Connecticut, and the treatment of them with copper sulphate was successful, at least it was followed by a happy result as far as the removal of the organism was concerned, and in that it was not followed by the development of any other organism.

One of the reservoirs was treated with copper sulphate to the extent of one part in nine millions. That reservoir was not in use at the time. The other reservoir was a larger one and was in use and was treated with copper sulphate to the extent of one part in about sixteen millions. This particular reservoir had

about forty colonies of *Uroglena* per cubic centimeter at the time of the treatment, and the odor of the water was exceedingly offensive in the town where it was used. The odor rapidly disappeared, so that at the end of four days there was no complaint of the water in the town, and there were none of the organisms to be found in a half liter of the reservoir water.

MR. D. D. JACKSON. The first experiments of the writer on the treatment of water with copper sulphate were made upon Baiseley's Pond, Jamaica, L. I., on September 6, 1904. As all of the water used from it is subsequently filtered, it was considered that there could be no possibility of the presence of copper sulphate after filtration, as this chemical does not remain in solution in the water, but is immediately precipitated by the carbonates present. At the time of treatment the pond contained a considerable growth of anabæna. On account of its gelatinous nature this organism was giving great trouble in the mechanical filters and had at times caused a reduction of as high as 25 per cent. in the rate of filtration. Table 1 gives the results obtained.

TABLE 1. — REDUCTION OF ALGÆ IN BAISELEY'S POND DUE TO COPPER SULPHATE TREATMENT.

Date, 1904.	Location.		Total Organisms.	Anabæna.
Sept. 6,	Top	Before treatment	1 640	800
" 6,	Bottom	" "	435	265
" 7,	Top	After "	155	55
" 7,	Bottom	" "	235	0
" 8,	Top	" "	105	0
" 8,	Bottom	" "	150	0
" 9,	Top	" "	125	0
" 9,	Bottom	" "	125	0
" 10,	Top	" "	175	0
" 10,	Bottom	" "	105	0
" 30,	Top	" "	140	0
" 30,	Bottom	" "	100	0

The amount of copper sulphate used was approximately 1 part in 8 000 000 parts of water, and the expense of treatment for 100 000 000 gallons was $7.50.

On the third day after treatment the wash water of the filter was reduced to 3 per cent., causing a saving in the yield of the plant for that time of 1 000 000 gallons per day.

Copper sulphate experiments were next made on an extremely heavy growth of clathrocytis, an organism closely related to anabæna, and one which is often found in large quantities in surface waters. This microscopic growth occurred in the Prospect Park Duck Pond near Flatbush Avenue, Brooklyn, in such enormous amounts as to entirely cover the surface of the pond with a thick green slime. Table 2 gives the results obtained by the treatment of this organism.

TABLE 2. — REDUCTION OF ALGÆ IN PROSPECT PARK DUCK POND DUE TO COPPER SULPHATE TREATMENT.

Date.	Location.		Units of Clathrocytis.
Sept. 9,	Top	Before treatment	700 000
,, 9,	Bottom	,, ,,	10 000
,, 10,	Top	After ,,	620 000
,, 10,	Bottom	,, ,,	83 000
,, 11,	Top	,, ,,	94 000
,, 11,	Bottom	,, ,,	35 000
,, 12,	Top	,, ,,	7 625
,, 12,	Bottom	,, ,,	2 550
,, 13,	Top	,, ,,	560
,, 13,	Bottom	,, ,,	640

The amount of chemical used was approximately 1 part in 4 000 000, and the cost of treating the pond was $2. During the present summer this treatment has been extensively used in the Brooklyn Department of Parks and has been found effectually to remove the disagreeable odor and unsightly appearance occurring so often in the park ponds, and in the dilutions used there has not been the slightest injury to shrubbery or fish.

During the month of September, 1904, a considerable growth of an alga known as aphanizomenon occurred in one of the sources of water supply for the borough of Manhattan, and its presence was the cause of a considerable taste and odor in the water.

On September 30, the surface of this reservoir was treated with copper sulphate in the proportion of 1 part to 8 000 000 parts of water. This amount of copper sulphate, providing it all remained in the water, would necessitate an individual to drink 100 gallons of water a day to get the slightest physiological effect from the copper, and there is, therefore, no question about the safety of such a treatment as this, especially as only one or two treatments a year are necessary. Table 3 gives the results obtained.

TABLE 3. — REDUCTION OF ALGÆ DUE TO COPPER SULPHATE TREATMENT, BOROUGH OF MANHATTAN WATER SUPPLY.

Date.	Location.		Total Organisms.	Aphanizomenon.
Sept. 30,	Top	Before treatment	4 680	4 100
„ 30,	Bottom	„ „	4 115	3 725
Oct. 1,	Top	After „	1 020	755
„ 1,	Bottom	„ „	565	285
„ 2,	Top	„ „	490	210
„ 3,	Top	„ „	140	0
„ 3,	Bottom	„ „	275	0

The figures of the above table show that this form of blue-green algæ was completely removed on the third day after treatment. From that time on the water has been clear and free from unpleasant odors.

Later in the year the microscopic organism uroglena occurred in large numbers in one of the Brooklyn supply ponds. This organism produced a strong fishy taste and odor in the water, and considerable numbers were being transported to the Ridgewood and Mt. Prospect distributing reservoirs. In order to prevent any further influx into the reservoirs of this odor-producing organism, the pond was shut off and a treatment with copper sulphate was made on November 23, 1904. As this is an extremely delicate organism a dilution was used of only 1 part of copper sulphate to 20 000 000 parts of water. Table 4 gives the remarkable results obtained.

TABLE 4. — REDUCTION OF UROGLENA DUE TO COPPER SULPHATE TREATMENT, BROOKLYN WATER SUPPLY POND.

Date.		Uroglena (Units per cc.)
Nov. 23,	Before treatment	1 100
Nov. 25,	Two days after treatment	450
Nov. 27,	Four days after treatment	0

During the present year no trouble has been experienced from microscopic growths in this pond.

In the spring of the present year one of the Brooklyn sources of supply was treated with copper in order to remove a growth of asterionella. It was found that 1 part of copper sulphate in 3 000 000 parts of water was necessary. Table 5 shows the results obtained.

TABLE 5. — REDUCTION OF ASTERIONELLA DUE TO COPPER SULPHATE TREATMENT, BROOKLYN WATER SUPPLY.

Date.		Asterionella.
May 2,	Before treatment	2 850
" 3,	" "	3 400
" 4,	" "	3 650
" 5,	After "	2 450
" 6,	" "	2 350
" 7,	" "	2 200
" 8,	" "	1 275
" 9,	" "	875
" 10,	" "	640
" 11,	" "	550
" 12,	" "	380
" 13,	" "	310
" 14,	" "	260
" 15,	" "	200
" 22,	" "	25

It will be seen from the above figures that not only does asterionella require more copper for its removal, but the reduction in the organisms appears to take place much more slowly.

Amount of Copper Necessary for Treatment. — The amount of copper required to remove a growth of micro-organisms from water depends to a large extent upon the structure of the particular organisms present. A definite amount of copper is required each time the treatment of any particular genus is made, excepting when the growth is extremely heavy, when it may be even necessary to double the quantity. In general the amounts of copper so far found to be required are as follows:

(PARTS OF WATER TO ONE OF COPPER SULPHATE.)

	DIATOMACEÆ.		
Asterionella	3 000 000	Synedra	1 000 000
Melosira	3 000 000	Fragilaria	4 000 000
	CYANOPHYCEÆ.		
Coelosphaerium	4 000 000	Anabaena	8 000 000
Oscillaria	5 000 000	Aphanizomenon	8 000 000
Microcystis	6 000 000	Clathrocystis	8 000 000
	CHLOROPHYCEÆ.		
Draparnaldia	3 000 000	Closterium	3 000 000
Scenedesmus	3 000 000	Volvox	4 000 000
Conferva	3 000 000	Spirogyra	5 000 000
Raphidium	3 000 000	Hydrodictyon	10 000 000

PROTOZOA.

Chlamydomonas	2 000 000	Mallomonas	2 000 000
Cryptomonas	2 000 000	Dinobryon	3 000 000
Euglena	2 000 000	Synura	10 000 000
Glenodinium	2 000 000	Uroglena	20 000 000
Peridinium	2 000 000		

It will be seen from the results that if the nature of the growth is not known a treatment of 1 part in 2 000 000 parts of water will be in all probability sufficient to accomplish the work. If, however, the organism is known, a much smaller amount may, in most cases, be used.

Recurrence of Growth. — It sometimes happens that a short time after a pond has been treated, and the growth removed, a second growth will develop. This second growth may be the same organism as the first, or it may be an entirely different organism. The fact that a second or third growth sometimes develops is in no way remarkable when we consider that the copper added is usually precipitated to the bottom in a few days and becomes inactive in the water above. If the conditions are favorable for a second development there is nothing but the reduction of spores to prevent its occurrence, but it has been noted that it is only in ponds or reservoirs highly contaminated with organic matter, and having large deposits of muck at the bottom, that such repeated growths do occur. In such cases, if the ponds are not cleaned, it may be necessary to treat them four or five times during the year. It has been claimed that a pond once treated with copper sulphate will require a stronger treatment for the second growth. This has not been the experience of the writer.

Influence of Copper on Bacteria in Water. — When a heavy growth of algæ is destroyed by treatment with copper, the dead organisms furnish food for the development of bacteria, and unless the algæ are rapidly precipitated to the bottom of the pond, then with the fall in algæ comes a marked rise in bacteria. Water bacteria require very strong solutions of copper to produce the slightest effect upon them. Table 6 shows the effectu pon the common water bacteria produced by the treatment of copper (1 part in 3 000 000 parts of water) in a reservoir containing asterionella.

TABLE 6. EFFECT OF COPPER SULPHATE ON COMMON WATER BACTERIA AFTER REDUCTION IN ASTERIONELLA.

1905.		Microscopic Organisms.	Bacteria.
March 13	Before treatment	4 625	405
„ 14,	After „	3 645	600
„ 15,	„ „	3 325	6 000
„ 16,	„ „	1 925	11 000
„ 17,	„ „	1 850	12 000
„ 18,	„ „	1 575	45 000
„ 20,	„ „	1 350	100 000
„ 21,	„ „	900	440 000
„ 22,	„ „	350	630 000
„ 23,	„ „	350	310 000
„ 24,	„ „	400	107 000
„ 25,	„ „	360	80 000
„ 26,	„ „	300	64 000
„ 27,	„ „	270	50 000
„ 28,	„ „	150	37 000
„ 29,	„ „	100	20 000
„ 30,	„ „	100	8 000
„ 31,	„ „	60	3 500
April 1,	„ „	25	860

PROF. W. P. MASON. Since listening to this very interesting discussion I cannot say that I am particularly enthusiastic about the use of copper sulphate for the removal of the typhoid bacillus from a drinking-water supply. There seems to be quite a bit of difference of opinion here. I noted in particular how much advantage was claimed from the accumulation of copper salts in the upper reaches of the sand bed. It seems to me that if we are obliged to use a filter anyhow, it scarcely would be wise to go to the expense of the introduction of copper sulphate before such use. The efficiency of the sand bed or of the mechanical plant, or of any good form of modern filter, is already high, and I do not believe that such efficiency is going to be materially increased by adding copper sulphate to the water before it is filtered. There is no question whatever that there is a very violent popular prejudice against such an addition.

DR. EDWIN L. NEWCOMB.* It seems to me the use of copper sulphate is not intended to replace the filtration beds, but it is

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simply intended to be used as an adjunct where we have insufficient filtration, or filter beds which are not deep enough to filter sewage or applied water so as to render the effluent suitable. The only point remaining is whether copper will kill typhoid and other organisms which pollute the sewage, or which render the water sewage, and if it is possible to kill them, then it seems to me it is a very valuable adjunct to the filter beds which do not sufficiently filter the water.

Dr. George T. Moore. I really do not think there is anything left for me to say. We have had a very full and interesting discussion, and a number of points have been referred to which I think all of us wish to clear up if possible. The discrepancy in the experience of the various ones who have reported requires some explanation, and I am sure that further opportunity for experiments along all lines will clear up matters which now seem doubtful.

It should be borne in mind that so far as the original projectors of the copper method of purifying water are concerned, it was not contemplated in any way to replace efficient means already in existence. Aside from the destruction of algæ, it was simply intended to suggest a possible emergency method for handling typhoid where a sand filter did not exist, and no other means for purifying the water were available. And under such conditions I still believe that the authorities would be justified in temporarily resorting to copper sulphate for purifying the water supply. The suggestion of the use of copper in destroying typhoid germs did not contemplate a continuous treatment, but rather the rapid sterilization, if I may use that term, of water which had been subjected to accidental pollution; a condition which would not occur again because of precautions immediately taken.

The other aspect of the question, the use of the method in connection with filters, is something with which we have had but little experience, and requires further experiments. Our intention and desire has been to put before the public all the information which could be obtained, and allow those who are competent to draw their own conclusions.

The same is true regarding the effect of copper upon man.

The very thorough and interesting discussion by Dr. Smith probably had one effect on those who consider copper a poison, and another on those who do not think it so. Any experience I have had with boards of health throughout the country would seem to indicate that mere evidence produced on either side of the copper question had little or no effect on the medical men present. It is, of course, practically impossible to introduce the use of copper sulphate into any community for any purpose whatever, where there is opposition of the medical authorities, whether state or local boards of health. And thus the thing really resolves itself into a local question. There is little use discussing the question or trying to prove that copper is or is not a poison, if you have the local board of health against you. They are usually not open to argument of the character which has been presented here. For this reason it is not probable that there will be any general adoption of a method of this kind, for, as Professor Mason says, there is undoubtedly a strong popular prejudice against the use of copper. This point, however, does not need discussion here, being one which must be considered entirely in the light of local conditions.

The point that Mr. Clark referred to, the standardizing of a test for copper, seems to me most important. We have had and will probably continue to have conflicting results regarding the presence of copper, or the amount of copper remaining in a water after treatment. Some of this may be due to the difference in the character of the water; probably a certain amount of it is due to the difference in the way in which the copper is determined. Any method which will result in getting comparable results, or standardizing the whole process, is much to be desired; and I hope that in the future, when comparisons of this kind are made, we may be sure that the methods used were the best and that they have been carried out most carefully. The only difficulty that I can see regarding the method that Mr. Clark uses is the fact that it is so complicated and requires the addition of so many different substances — distilled water, various acids, etc., — which, of course, must themselves be tested for copper. In incompetent hands, outside of well-equipped laboratories, the chances for mistakes and the finding of large quantities of

copper where little or none occurs in the water, by such a method, are greatly increased. For this reason I wish we might have a simpler method which could be used universally and thus eliminate as much as possible the opportunity for error.

Dr. Frederick S. Hollis * (*by letter*). In the various papers presented that have treated so fully all sides of the copper sulphate method, we are fortunate in having records from different sections of the country, representing the action of copper sulphate on organisms growing in waters having markedly different characters, especially in regard to hardness and alkalinity, and probably, too, in the amount of organic matter in solution such as gives the color to our northern waters.

Water like that reported from Ohio, having hardness as high as 400 and alkalinity 100, will naturally precipitate the copper more promptly and completely than a Massachusetts or Connecticut water having hardness and alkalinity of from 10 to 20, and it is probable, too, that certain organic matter held in solution in the water, as well as carbonic acid, may have considerable to do in retarding precipitation. Those of us who have made applications of the method have generally been asked how long the sulphate added will act to keep down the growths and whether the successful removal of a growth one season will prevent it from occurring the following year. Neither of these questions can be answered definitely, but, from what has already been brought out, I feel that I have been quite safe in stating that in most waters probably enough will not remain in an active form to act very long after the time of treatment. The complete or nearly complete removal of a form of growth ought, through the prevention of the formation of spores from which the growth in the following season starts, to greatly lessen the chances for a repetition of the growth. On visiting the reservoirs from which a growth of Anabæna was removed last summer at the time when the growth last year was at its height, only a negligible amount of Anabæna was found and the water had up to that time given no trouble from any growth.

That judgment is necessary in making the application so as

* Yale Medical School, New Haven, Conn.

to avoid the loss of sulphate due to settling from the line of strong solution following the boat, in case there is not sufficient wind to effect rapid and complete mixing, has already been mentioned. In the applications that I have made, I have calculated that the sulphate added necessary to give for the entire contents of the reservoir an amount equal to 1 part in 5 000 000 or .2 part per 1 000 000, really went into solution in a line having a strength of 1 part in 250 or 4 000 parts per 1 000 000. These applications were all made when there was considerable wind and in comparatively shallow reservoirs, where the wind influences easily reached to all depths.

While making the applications unsparingly over the shallow flowage and areas covered with water weeds, which I determined to be the breeding places of some of the forms that it was desired to remove, it has not been my misfortune to kill any fish, although the reservoirs were well stocked with bass, pickerel, perch, and eels. Bacteria I have found to increase, in one case twentyfold, after an application of .2 part per 1 000 000, which is readily accounted for by the increase of food material supplied by the bodies of the forms that have been killed. All of the accounts show the absolute necessity of the careful determination of the microscopic forms present before making the application because of the great difference in susceptibility of different forms.

The results show clearly that two of the most objectionable forms, Anabæna and Uroglena, yield to amounts so small that there ought to be no prejudice against its use, and that the value of the method cannot be overestimated even if only for the restriction of these two forms.

Growths of many forms are retarded or held in check by an amount of sulphate inadequate to exterminate them, while in my experience a growth of Chlamydomonas increased following the treatment for the removal of Anabæna, imparting its sharp odor and taste to an extent sufficient to offset largely the value derived from the complete removal of Anabæna. Fortunately growths of Chlamydomonas are uncommon and such a case would rarely be met with. While in writing an account of my tests I used the method that has commonly been employed in recording the amount of copper sulphate, I, with others, would

favor reporting it in parts or decimals of a part per million, uniform with the method of reporting chemical analysis.

Copper Sulphate as an Adjunct to Sewage Disposal.

BY EDWIN L. NEWCOMB, PHARM. D. [*By letter.*]

One of the most useful purposes which copper sulphate promises to serve in the purification of waters is in the treatment of sewage.

Before giving the results of the experiments which I have carried out along these lines, I wish first to state the conditions with which I have had to deal.

The disposal field upon which I have been experimenting is located at Vineland, N. J., and consists of eight filter beds and three settling beds, or septic tanks, which are used at present for separating out the larger portions of solid matter and obtaining a septic action. The filter beds are from 150 × 150 feet to 150 × 200 feet in dimensions, and the amount of sewage to be cared for daily is approximately 280 000 gallons. The filtering material in the filter beds consists of coarse cinders around the drain tiles, gradually decreasing in coarseness until the natural soil is reached, which consists mostly of fine sand and some gravel. This layer of filtering material varies from two feet in thickness at the upper side of the field to about four feet at the lower side; through this thin layer of filtering material an exceedingly rich sewage must pass, and a filtrate suitable to enter a drinking-water supply be obtained.

Experience has taught that it is almost impossible to filter a rich sewage through such a thin filter as this and obtain a filtrate which is fit to enter a drinking-water supply.

The surrounding physical conditions being such that it was impossible to increase the depth of the filters, and as the filtrate was badly contaminated with intestinal organisms, I decided, after consulting Dr. Moore and Mr. Kellerman, of Washington, D. C., to try copper sulphate.

In connection with Mr. Kellerman, I went over the system, and together we laid out a plan of procedure; an examination was made of the raw sewage, both chemically and bacteriologically; the only apparently interfering substance from a chemical point of

view was the organic matter, which was largely albuminoid in form, and hence would have a great tendency to precipitate out the copper salts.

Space will not permit me to give in detail the results of all the experiments carried out; a brief summary will be all that is possible here.

Copper sulphate was first applied to the raw sewage in a quantity such that it made a solution, approximately, 1 part of copper sulphate to 100 000 parts of sewage. The copper was added in concentrated solution by means of an automatic feed. The first noticeable results were that the gate chambers and connecting pipes between the beds attained a much more sanitary condition, so that there was almost no odor due to algæ, with which they were previously infested. It was also noticeable that a large quantity of copper had been precipitated out by organic material and floated about the surface of the filter bed; this was probably an albuminate of copper possessing less germicidal properties than the sulphate.

The bacteriological examination of the filtrate showed that there was a gradual decrease in the number of intestinal organisms, and at the end of eight days no coli developed on litmus lactose agar, and there was also a very noticeable decrease in the total number of organisms. The results of these tests were satisfactory in a measure, but not altogether, for some counts showed that there seemed to be a deficiency of copper, due, no doubt, to the fact that at times more was precipitated out by the organic matter.

I therefore began using the settling beds as septic tanks and adding copper sulphate to the clarified sewage as it came from these tanks. By this manner of operation the larger portion of organic matter is broken up by the action of the nitrifying organisms in the septic tanks; therefore, only a small quantity of copper is lost by precipitation. It has been proven that where bacillus coli and other intestinal organisms were found in the filtrate from the beds when no copper was used, there were absolutely no intestinal organisms to be found after the use of copper sulphate; thereby rendering the effluent free from pollution and fit to enter a drinking-water supply.

The determination of sewage can no longer be made upon a chemical analysis alone, for as Dr. Henry Kraemer of Philadelphia stated, "Although previous authority based the determination of sewage on the amount of nitrites, chlorine, ammonia, etc., this can no longer be taken as a criterion, as a water supply may contain any or all of these substances, and at the same time not have a single trace of sewage present." "Sewage, according to the modern translation of the word, is any water which contains coli organisms."*

The determination of the exact amount of copper sulphate necessary to render water free from coli is as yet a problem, the two chief factors which determine the amount necessary in this case being temperature and the amount of organic material. At one time I was using but one part of copper sulphate to 175 000 parts of sewage, but a change in temperature caused me to return to 1 part to 100 000 of sewage.

Tests have been made repeatedly for copper in the filtrate by the delicate potassium ferro-cyanide test, and the water at all times has given no discoloration.

In conclusion, it has shown that where filtration plants fail to do satisfactory work, due to the non-elimination of intestinal organisms, copper sulphate is a practical means by which the filtrate may be rendered free from disease organisms, and as has been stated by Dr. Kraemer, "It has the added advantage of completely destroying the organisms, as well as removing them." †

Notes on the Use of Copper in China.

BY S. P. BARCHET, M.D.‡ [*By letter.*]

Copper and brass cash are the standard coin of China, handled daily by old and young. Copper also figures largely in the make-up of kitchen utensils; copper ladles, copper kettles, and copper pots being in general use.

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* "Third Report on Experimental Work on Sewer Beds, Vineland, N. J.," by Edwin L. Newcomb.

† Amer. Med., Vol. ix, No. 7.

‡ Annapolis, Md.

It is no uncommon sight in Mid-China to see rice boiling in copper pots with verdigris around the rim, yet the people who eat the rice are hale and hearty.

Foreigners who, to my knowledge, have partaken of food prepared in copper vessels, did not suffer in any way.

In my medical practice, extending over twenty odd years in the Province of Chegiang, I met with not a few cases of poisoning by opium; also with a few cases of poisoning by salts of mercury, or arsenic; but I never saw there a case of poisoning by copper.

Children who had swallowed cash were occasionally brought to the hospital, but apart from mechanical obstruction, no untoward symptoms developed in those cases. Nor have I seen a case of copper poisoning recorded in any of the medical reports of mission hospitals in China.

It may be that the long-continued use of copper has made the Chinese not so susceptible to the irritant action of copper salts, or that the minute quantities swallowed are insufficient to produce characteristic symptoms.

From extensive applications of the sulphate of copper in certain troubles of the eye, I have only seen beneficent results.

The remarkable power of copper and its salts as an algicide and germicide, as demonstrated by Drs. Moore and Kellerman, throws some light on the comparatively good health of crowded and insanitary Chinese cities, whose inhabitants drink mainly hot water, tea, or wine, boiled in copper vessels.

Mr. G. C. Whipple (*by letter, November 27, 1905*). During the last few days I have had an opportunity of looking over a report made to the Brisbane, Australia, Board of Water Works by Mr. Hardolph Wasteneys, analyst of the board.

The report is dated May 15, 1905, and relates to an experimental investigation of the effect of copper sulphate on algæ. The results of Mr. Wasteneys' experiments do not differ greatly from those which have been obtained in the United States. The organisms which he has had to contend with, however, are somewhat different from those which are common in these regions. In particular he mentions a form called Microhaloa, which is said to be similar to Palmella hyalina, although somewhat larger. The most common

organisms present in the water at the time when he made his experiments were Microhaloa, Anabaena, Spirogyra, and Peridinium. These organisms were practically all killed in forty-eight hours with one part of copper to four million parts of water. The Microhaloa and Anabaena succumbed with one part of copper to eight million parts of water.

Mr. Wasteneys' report gives his results in full detail, using the standard methods so well known in this country.

He also experimented with large sheets of copper suspended in running water, but found that, although it retarded somewhat the growth of the zygnema which was present in the water, it by no means killed it, and his conclusion was that the use of sheet copper as an algicide would not be successful in practical applications to their water supply.

Some of his descriptions of the occurrence of algæ in the reservoirs of the Brisbane Water Works are of much interest, and we may hope to have, at some time in the future, a paper by Mr. Wasteneys describing the work which he is doing in Brisbane.

Mr. C. Arthur Brown * *(by letter)*. I have listened to the papers read with much interest and some perplexity. It seems strange that such wide differences of opinion as to the removal of copper and its salts from water should exist among the workers who have taken part in this discussion. Evidently something is wrong. Even admitting that there is a certain amount of prejudice among those experimenting along this line, the expressions are at too great variance to be explained on this basis. I think one or two of the speakers have touched on what is probably the real trouble. It is, I think, necessary to know more about the type of water which is to be treated and to understand more thoroughly the reactions which will occur when copper or its salts are added to such a water.

My belief is that the work must be brought to a more scientific basis, and the men using these materials must do their work along better defined lines and with less guessing at what is going to be the result. It seems to me we have not found as yet the underlying principle on which good work must be done and

* Lorain, Ohio.

satisfactory results secured. Possibly I may be able to add my mite to the sum total of knowledge on this subject.

Ignoring, if I may, the question as to whether copper is or is not injurious to water users, if present in small amounts in potable waters, I wish to give briefly my experience and to state in a general way the results obtained by its use. In my early work on the use of copper sulphate, I found it necessary to know positively the character of the water to be treated, and likewise, the character of the water after treatment. I soon found that if the water to be treated contained as much half-bound carbonic acid as it did combined carbonic acid, the tendency was to hold copper in solution for a greater or lesser period of time. If a large amount of organic matter was present, this tendency was stronger, and if, in addition, some free carbonic acid was present, the tendency was still stronger. This led me to attempt to secure the removal of the copper by establishing different conditions. I soon found that if the free carbonic acid and a small portion of the half bound could be absorbed by caustic lime, then copper sulphate could be added with impunity, in reasonable quantity, and the consequent removal, either by sufficient sedimentation or filtration, was as perfect as could be desired. I also found that the precipitated copper was as efficacious, apparently, as a germicide as was necessary, and if it was allowed to accumulate on a filter bed, manifested no tendency to go into solution again.

These theories were given a practical test at Anderson, Ind., in the filter plant installed by the city, which was then furnishing water to supply the demands of Anderson. A summary of this test has been reported by Dr. Moore and Mr. Kellerman in their last "Bulletin" on this subject. The removal of the copper seemed to be complete, 10 liters of the filtered water being used for the purpose of testing for the presence of copper. Some criticism was offered on the quantity used for testing, the critics claiming that the amount taken was not large enough. Another test of the process was made at a later date at Marietta, Ohio. This test was also on a large scale. In taking the samples to be tested for copper at this point, I tried to use as large a quantity of the filtered water as was practical, taking a 200-gallon sample and evaporating to dryness. Later on, Professor Monfort took

100 gallons for the same purpose. The fact that copper is found in so many substances led me to think that it might possibly be found in natural water if large enough quantities of the same could be examined. At the time the filtered sample was taken, I therefore took 200 gallons of the river water and subjected it to test. The 200 gallons of river water yielded 0.10015 grams of metallic copper, while the 200 gallons of filtered water contained 0.00275 grams of metallic copper. It was afterwards ascertained that the latter amount was too large in all probability, as care had not been taken to collect the sample before passing the pumps and other brass fittings; but even assuming the amount present in the filtered water to be correct, there is shown to be present only 1 part of copper in 275 286 000 parts of water, while the river water in its normal condition at that time carried thirty-six times as much copper. Yet people have drunk this water as far back as our knowledge goes, and we have no record of copper having any injurious effects upon them.

Later determinations by Professor Monfort and myself of the amount of copper in the river and filtered waters, the filtered water being taken under additional precautions to prevent recontamination by copper, confirmed the results above given, with the exception that the quantity found in the filtered water was proven to be much smaller. These results were checked often enough to make us certain of our position.

In this case, we find that 97 per cent. of the copper present in the river water is removed by this process, and in addition, *all* the copper used in filtering is taken out as well. The reason is easily seen. Copper sulphate is practically insoluble in a water containing normal carbonates. By absorbing a small portion of the half-bound carbonic acid, we brought about the presence of normal carbonates in the water to which the copper salt was added. The water entering the settling basins of the filter plant, after the lime, iron, and copper had been added, gave a distinct reaction to phenolphthalein.

It is my belief that some of the results obtained by the others who have spoken on this subject were not such as would have been secured had they established the conditions above spoken of. If enough caustic lime is added to absorb all of the free and a

portion of the half-bound carbonic acid, you can then apply salts of copper and secure practically complete elimination. This does not interfere in any way with the germicidal action of the copper salt as far as I have been able to ascertain. A complete report of the work done at Marietta will appear within a very short time. I shall not say a great deal about the bacterial results obtained, but I should like to mention the fact that no sample of the filtered water contained *B. coli communis*.

MR. GEO. T. PRINCE.* A small lake located in one of the parks of Denver has given reason for complaint during past seasons because of the offensive odor that arises as a result of the presence of micro-organisms in the water. It was determined to try the effects of copper sulphate not only as a remedy to this trouble but also to gain some knowledge from experience in determining whether we would resort to copper sulphate in any of our reservoirs should occasion require.

The lake was treated on August 10, last, the temperature of the water at the time of treatment being 24.5° C. The capacity was estimated at 4 000 000 gallons and the lake covers approximately one acre of ground. Sixteen pounds of copper sulphate of a solution of one part in two million parts of water were applied. All samples were taken at a certain point throughout the experiment. The sample taken just before treatment contained a vast amount of microscopic organisms. Most of these organisms can be grouped under the head of cyanophyceæ, or blue-green algæ. They consist of ananbæa circinnalis, anabæna flos aquæ, aphanizomenon and clathrocystis and the number of standard units of each was noted.

The bacteriological analysis before treatment showed 6 200 bacteria per cubic centimeter. The sample also contained *bacillus coli*.

A blue-green surface scum was scattered over the greater portion of the lake.

The copper was applied by placing it in two gunny sacks which were suspended over the stern of a boat that was rowed over the surface of the lake. It took about two hours to complete the treatment.

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*Chief Engineer, Denver Union Water Company, Denver, Colo.

About twelve hours after treatment a sample of the water was taken and no trace of anabæna could be found. Aphanizomenon had almost disappeared and about 25 per cent. of the clathrocystis. Twenty-four hours after treatment a thick scum had collected in one arm of the lake near the inlet. A blue-green scum was also visible around the edges on the shore. The sample taken at this time showed an entire absence of anabæna and aphanizomenon and a reduction of over sixty per cent. of clathrocystis. Very little effect on the crustaceæ was noticeable, except they were more sluggish in their movements. The number of bacteria was 135 000, multiplication evidently being due to the increased supply of food furnished by the dead algæ. Tests for coli were negative.

Forty-eight hours after treatment the water was quite turbid and the surface scum remaining was scattered throughout the lake. The clathrocystis was apparently dead and only twenty per cent. of the original amount was present. The diatom navicula showed no signs of life at this time. A few dead crustaceæ were found also. About the same number of bacteria were found, the count being 130 000 per cubic centimeter.

On the third day the water looked much clearer and the surface scum was practically all gone.

On the fourth day another sample was taken and no algæ were to be found. The bacteria had decreased to 82 000. The water was much clearer and no scum was visible.

It was not deemed necessary to prolong the investigations further.

Tests were made for copper sulphate in 1 000 cubic centimeters of the sample taken on the fourth day and the reaction was negative. The delicate posassium ferrocyanide test was used. By this test it is possible to detect 1 part of copper in 2 500 000 parts of water.

In the latter part of September one of our reservoirs was so badly affected by the presence of anabæna that we decided to resort to copper sulphate as a remedy. The reservoir at this time covered 600 acres of ground and contained approximately 4 500 000 000 gallons of water. We began to apply the sulphate at 2.30 P.M., October 6, and the work was continued during that day,

the following day, and half of the next day. We used in all 10 000 pounds of copper sulphate. The sulphate was placed in gunny sacks, each of the sacks containing about seventy-five pounds. A gasoline launch was used in the process of applying the sulphate, three bags being suspended on each side of the launch from outriggers.

Analyses were made, both biological and bacteriological, of the samples of water taken before treatment and every twenty-four hours after treatment for five days, also the delicate potassium ferrocyanide test was used in determining the presence of copper in the water but with negative results, showing that the copper had been entirely absorbed by the micro-organisms in the water.

The application of copper sulphate had an immediate effect upon the microscopic life contained in the water and also upon the odor. It will be noticed that anabæna disappeared entirely within twenty-four hours after treatment and that the more persistent organisms gradually succumbed to the influence of the copper until, nine days after treatment, the analysis shows the water to be practically free from these micro-organisms with the exception of bacteria, which, as will be observed, multiplied very rapidly after the copper sulphate had been applied to the water, due undoubtedly to the presence of dead algæ.

The color of the lake water was changed in consequence of the treatment and resembled more a body of salt water than fresh in appearance.

The results were very satisfactory and the condition of the water in the lake made it possible to place the lake in service.

The bacteriological count has decreased rapidly and on October 25 there were present 4 750 colonies per cubic centimeter.

NEW ENGLAND WATER WORKS ASSOCIATION

TABLE SHOWING EXPERIENCE IN THE USE OF COPPER SULPHATE FOR REMOVING ORGANISMS FROM WATER

(Compiled from statements received from persons who have used this treatment)

Place	Body of Water Treated: Name	Cap. Million Gallons	Area Acres	Organisms Causing Trouble	Date	Ratio, Million Parts of Water to one of Copper Sulphate	Treatment, Effect: On Organisms	On Tastes and Odors	On Fish	Reappearance of Organisms in Same Year: Organism	Length of Time since Treated	Extent	Remarks
New Hampshire Hanover	Reservoir	19		Uroglena Anabæna	July, 1902	4.0	Destroyed in 3 days	Disappeared in 3 days	None				
				Uroglena Anabæna	May, 1903	4.0	Destroyed in [illegible] days	Disappeared in [illegible] days	None	Uroglena Anabæna	[illegible]		[illegible]
Massachusetts Arlington	Reservoir	65	[illegible]	Scenedesmus	August 5, 1903	1.8	None	None	None				
				Anabæna Aphanizomenon Staurastrum	July 18, 1904	3.7	Anabæna [illegible] Aphanizomenon [illegible] destroyed; Staurastrum, none			[illegible] Protococcus Scenedesmus Staurastrum	Developed [illegible]	Large numbers	August [illegible] the reservoir was again treated [illegible] August 30 the reservoir was again treated [illegible]
Belchertown	Reservoir	55	[illegible]	Chara Anabæna	July 2[illegible], 1904	8	Anabæna destroyed; Chara, none	Disappeared in [illegible] days	None	Tabellaria Asterionella	[illegible]	Large numbers	No further treatment
		35 when treated		Chara Anabæna	June 13, 190[illegible]	[illegible]	Anabæna nearly destroyed; Chara [illegible]	Improved slightly	None	Anabæna	[illegible]	Large number	Again treated with one part copper sulphate to [illegible] [illegible] and taste and smell disappeared
Newton	Crystal Lake	143.0	31.0	Anabæna	August 18, 190[illegible]	[illegible]	Destroyed	Disappeared	None or all bass killed				
Jamaica Plain	Jamaica Pond	600.0	69.0	Oscillaria	September 25, 1903	[illegible]	Fell off slightly	**	None				
				Oscillaria	August 19, 1905	1.8	Disappeared in [illegible] weeks	**	Killed about [illegible] fish—suckers, bass, perch and sunfish				
Lexington	Reservoir	8.0	[illegible]	Uroglena	June 30, 1905	[illegible]	Destroyed	Disappeared	None				
Sharon	Massapoag Lake	1142.0	350.0	Anabæna	November, 1904	5.0	Destroyed		[illegible] killed. Essentially small perch and suckers				
Connecticut Greenwich	Rockwood Reservoir	325.0 (235 when treated)	91	Confervæ Spirogyra Anabæna Chlamydomonas	July [illegible], 1904	5.6	Anabæna destroyed, others greatly reduced	Improved till Chlamydomonas developed	None	Essentially Chlamydomonas, also Diatomaceæ and Chlorophyceæ	[illegible] week	Slightly larger numbers	The reservoir was treated [illegible]
	Putnam Reservoir	300.0 (150.0 when treated)	100	Tabellaria Anabæna	July [illegible], 1904	5.2	Anabæna destroyed, others greatly reduced	Improved permanently	None	Tabellaria Chlamydomonas		Smaller [illegible]	The reservoir was [illegible] per cent
New York Amsterdam	Reservoir	100.0	11.5	Anabæna	July 1, 1905		Destroyed in [illegible]	Disappeared	None	Anabæna		[illegible]	[illegible]
Clinton	College Reservoir	[illegible]		Chara	July [illegible], 190[illegible]	[illegible]	Checked growth	**	**				August [illegible]
Elmira	Impounding Reservoir	113 (90 when treated)	18.0	Asterionella Anabæna	June, 1905	1 (about)	Destroyed in 5 days	Practically eliminated	A few killed				Anabæna [illegible]
Hartwood	Hemlock Lake	[illegible]	37.5	Anabæna	July 11, 1905	2	Destroyed	Disappeared [illegible]	[illegible] killed [illegible] pickerel [illegible] This was a small percentage of the fish in the lake				
Middletown	Shawangunk Reservoir	316.6	15.0	Oscillaria Anabæna	June [illegible], 1905	1.9	Destroyed	Disappeared	Few small trout killed		[illegible] months		
	Highland Reservoir	451.0	110.0	Protococcus Oscillaria	July 15, 1905	2.4	Destroyed	Disappeared	Considerable number killed, principally [illegible]		[illegible] months		
	Monhegan Reservoir	255.0	74.0	Anabæna	July [illegible], 1905	1.2	Destroyed in [illegible] days	Disappeared	None		[illegible] months		
Waldheim Scarboro' on Hudson		4.0		Hydrodictyon	June 16, 1904	5.5	Destroyed in 3 day				*		
Water Mill	Pond	11.5		Cladophora Enteromorpha	June, 190[illegible]	3.0	Destroyed in 7 days		None		*		
				Cladophora Enteromorpha	July [illegible], 1905	3.0	Destroyed						[illegible]
New Jersey Atlantic City	Basin	0.6	[illegible]	Ulothrix	May 27, 1905	See Remarks	Destroyed	**	**	Ul[illegible]		[illegible]	The water in this basin [illegible]
Pennsylvania Millersburg	Reservoir	[illegible]		Fragilaria	May [illegible], 1905	2	Destroyed	Disappeared	Several killed	Fragilaria	[illegible] weeks	[illegible] smaller numbers	The [illegible]
Williamsport	Upper Reservoir	21	[illegible]	Chlorophyceæ algæ	May 15 and 27, 1905	1.5	Destroyed	None	None	Chlorophyceæ algæ	[illegible] week	[illegible] May	The [illegible] both reservoirs were again treated [illegible]
	Lower Reservoir	[illegible]	[illegible]	Chlorophyceæ algæ	May [illegible], 1905	1	Destroyed	None	None	Chlorophyceæ algæ	[illegible] weeks	[illegible]	
Maryland Port Deposit	Reservoir	1	2	Chlamydomonas	May [illegible], 1904	[illegible]	Destroyed	Disappeared	None				
South Carolina Charleston	Reservoir	1,134.0	[illegible]	Crenothrix Anabæna Oscillaria	About 1 month was occupied in dissolving the copper sulphate	[illegible]	Destroyed	Disappeared		Oscillaria Anabæna	[illegible] months [illegible] months	[illegible] numbers [illegible] numbers	The reservoir was treated when the Anabæna appeared [illegible] before destroying the Anabæna [illegible]
Greenwood	Reservoir	0.5	[illegible]	Conferva	June 15, 1905	1.2	Destroyed	Disappeared	**	Not known	[illegible] days	[illegible]	Treated [illegible] greater [illegible]
Ohio Oberlin	Reservoir	[illegible]	[illegible]	Chara	May 24, 1905	2.0	Large numbers were killed	None	[illegible] killed				The reservoir was treated [illegible] before [illegible]
Indiana Anderson	White River			Oscillaria	July 16, 1905		Slight diminution in numbers	Improved		Oscillaria	Few days	[illegible]	No further treatment. [illegible] up stream [illegible]
Illinois Leclaire	Artificial Lake	25.0	7	Spirogyra	July 18, 1905	6.0	Destroyed in [illegible] days	None	None	Spirogyra	[illegible]	Smaller numbers	No further treatment
Springfield	Lily Pond	[illegible]	[illegible]	Conferva Spirogyra	May 24, 190[illegible]	[illegible]	Destroyed	None	None	Conferva	[illegible] week	About one half that amount before treatment	The pond was again treated June [illegible] destroyed
Colorado Denver	Lake in City Park	[illegible]	[illegible]	Navicula Anabæna Clathrocystis Aphanizomenon Rotifera	August 10, 1905	5.0	All destroyed in 4 days						
	Marston Lake Reservoir	4,500.0	600.0	Anabæna Synedra Stephanodiscus Ceratium Peridinium	October 6 and 7, 1905	3.7	All destroyed in 4 days	Disappeared in 3 days					
Montana Butte	Basin Creek Reservoir	190.0		Anabæna Asterionella	July 6, 1905	8.5	All destroyed in [illegible] days						

** Indicates no tastes or odors or fish present before treatment. * Indicates the non reappearance of organisms. [illegible]

NOTE. — Reports were received from about twenty other places, where the troublesome organism was merely said to be algæ. These have been grouped together, and the following statement is [illegible] these results. Of the [illegible] the treatment was successful in each case, but in thirteen of them the organism reappeared the same year. These places where the algæ reappeared were distributed over the country.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, November 8, 1905.

George Bowers, President, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, George Bowers, Dexter Brackett, E. C. Brooks, James Burnie, F. H. Carter, J. C. Chase, D. D. Clarke, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, G. E. Crowell, A. W. Cuddeback, F. F. Forbes, E. V. French, F. L. Fuller, T. C. Gleason, A. S. Glover, R. A. Hale, J. O. Hall, L. M. Hastings, T. G. Hazard, Jr., H. G. Holden, F. S. Hollis, J. L. Howard, W. S. Johnson, Willard Kent, F. C. Kimball, G. A. King, L. P. Kinnicutt, W. W. Locke, D. E. Makepeace, A. D. Marble, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. L. Northrop, T. W. Norcross, J. B. Putnam, H. E. Royce, C. W. Sherman, W M. Stone, G. H. Snell, G. A. Stacy, J. T. Stevens, H. L. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, C. K. Walker, R. S. Weston, C. E. A. Winslow, G. E. Winslow, F. E. Winsor. — 60.

Honorary Member.

William T. Sedgwick. — 1.

Associates.

Roy S. Barker; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, W. A. Hersey; International Steam Pump Co., by Samuel Harrison; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates and C. L. Brown; A. P. Smith Mfg. Co., by F. N. Whitcomb; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by Frank L. Northrop and W. F. Hogan; Water Works Equipment Co., by W. H. Van Winkle. — 18.

Guests.

J. D. Ferguson, Scituate, Mass.; Raymond W. Kent, Cambridge, Mass.; J. H. Howland, Supt. Water Works, Honolulu, H. I.; F. E. Adams, Boston; Murray Millikin, Boston. — 5.

[Names counted twice. — 3.]

The following were elected members:

Lewis R. Davis, Pittsburgh, Pa.; Stanley A. Miller, Asst. Engineer Mexican Light & Power Co., Necaxa, Puebla, Mexico; Donald M. Belcher, Sanitary Engineer, Charleston, S. C.; John Hastings Howland, Asst. Superintendent of Public Works and Superintendent of Water Works, Honolulu, H. I.; Alexander Orr, Superintendent of Water Works, Gloversville, N. Y.; Warren U. C. Baton, Asst. Chemist, Washington Aqueduct Filtration Plant, Washington, D. C.; George T. Moore, engaged in sanitary work connected with water supplies, Washington, D. C.; George C. Warren, President Water Commissioners, Saginaw, Mich.; James Lyford Davis, Asst. Engineer, Aqueduct Commission, New York; John Byron Goldsborough, Croton-on-Hudson, N. Y.; E. L. Grimes, Troy, N. Y.; Ernest C. Levy, M.D., Director of Laboratory of Water Department, Richmond, Va.; Jules Breuchaud, Yonkers, N. Y.; Joseph F. Regan, Jr., General Manager Consolidated Water Co., Utica, N. Y.; Albert L. Webster, Civil and Sanitary Engineer, New York City; Theodore D. L. Coffin, in charge of the Long Island Filter Plants, Jamaica, L. I.; H. W. Clark, General Manager and Treasurer of Mattoon Clear Water Co., Mattoon, Ill.; William Naylor, Superintendent of Water Works, Maynard, Mass.

The paper of the afternoon was by Profs. W. T. Sedgwick and C.-E. A. Winslow of the Massachusetts Institute of Technology, on "The Present Relative Responsibility of Public Water Supplies and Other Factors in the Causation of Typhoid Fever." It was followed by a discussion by Mr. E. E. Lochridge, Engineer of the Water Department, Springfield, Mass.; Dr. George Burgess Magrath, Acting Secretary of the State Board of Health; Professor Winslow, Prof. Leonard P. Kinnicutt, Robert S. Weston, Dr. Frederick S. Hollis, and Wm. W. Locke.

Adjourned.

EXECUTIVE COMMITTEE.

Boston, Mass., November 8, 1905.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Wednesday, November 8, 1905, at 11.30 A.M.

Present: President George Bowers and Charles W. Sherman, Frank E. Merrill, F. W. Gow, George E. Crowell, George A.

Stacy, L. M. Bancroft, James Burnie, James L. Tighe, and Willard Kent.

The Secretary read the applications for membership from the following persons:

Donald M. Belcher; E. L. Grimes; Alexander Orr; John F. Reagan, Jr.; Albert L. Webster; Jules Breuchaud; John Hastings Howland; Ernest C. Levy, M. D.; Lewis K. Davis; Theodore D. L. Coffin; William Naylor; H. W. Clark; Warren U. C. Baton; Stanley A. Miller; George T. Moore; George C. Warren; James L. Davis; John B. Goldsborough;

and it was voted to recommend the applicants for election.

On motion of Mr. Stacy, seconded by Mr. Tighe, it was voted: That the February meeting of the association be recommended for Ladies' Day.

Adjourned.

Attest: WILLARD KENT, *Secretary*.

OBITUARY.

AURELIUS G. PEASE, water commissioner, Spencer, Mass., died September 20, 1905, at Phœnix, B. C., where he had gone on a vacation trip. He was sixty-eight years of age, and had been in business in Spencer for thirty years. He leaves a wife and one daughter.

Mr. Pease became a member of the New England Water Works Association on June 16, 1886.

BOOK NOTICES.

Report of the New York Bay Pollution Commission: Daniel Lewis, Olin H. Landreth, Myron S. Falk, George A. Soper, Louis L. Tribus, Commissioners. [State of New York, Senate Document No. 39, 1905.] 135 pages and folded map.

The question of the pollution of New York Bay by sewage is obviously one of great importance, and the difficulties in the way of a satisfactory solution, due to the division of jurisdiction between the states of New York and New Jersey, are serious. This commission was appointed in June, 1903, and reported on March 31, 1905. The several members of the Commission took up individually the investigation of branches of the main subject, and their detailed reports are given as appendices to the report of the Commission. Its recommendations are, that the State of New York bring action in the United States Supreme Court against the State of New Jersey and the Passaic Valley District Sewerage Commission, to prevent the discharge of the sewage of that district in the harbor; and that a Metropolitan District Sewerage Commission be appointed to continue the work, and to make comprehensive plans for the sewage disposal of the whole New York Metropolitan District.

Thirty-sixth Annual Report of the State Board of Health of Massachusetts, for the year 1904.

In addition to the advice to cities and towns, and experiments on purification of sewage and water, which are regular features of these reports, the present volume contains a report on examination of public water supplies, covering some seventy-five pages, giving the averages of the chemical analyses of all the water supplies of the state for the last five years, and also grouping the several sources in the order of their chemical constituents, there being a separate table for each of the more important substances shown by chemical analysis, as well as for color, odor, and hardness. The water supply statistics given also contain the consumption of water for all supplies in the state of which records are available, as well as records of rainfall and flow of streams for the year.

JOURNAL

OF THE

New England Water Works Association.

VOLUME XX.

1906.

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION,

715 Tremont Temple, Boston, Mass.

The Fort Hill Press
SAMUEL USHER
176 TO 184 HIGH STREET
BOSTON, MASS.

INDEX.

WILLIAM T. SEDGWICK.

President New England Water Works Association.

1906

(See page 94.)

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XX. March, 1906. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

WATER PRESSURE REGULATORS.

BY A. O. DOANE, DIVISION ENGINEER, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read December 13, 1905.*]

The problem of providing the proper water pressure for all parts of a water-works system supplying a territory having considerable variation in elevation is somewhat difficult, as very often when an attempt is made to give a good fire service in the higher portions, the lower parts, if supplied from the same source, will have too much pressure for proper domestic service.

A solution often adopted is to have high and low service districts supplied with separate mains. In cases where the low-lying portion is small in comparison with the higher parts of the district, pressure regulators are sometimes employed. If the supply is by gravity from a source so elevated that the direct pressure would be too high, pressure-reducing apparatus may be employed to provide a proper domestic service.

These appliances are also useful when the water mains are too weak to withstand the higher pressure, as in some old cement-lined pipe systems. A dangerous district may be supplied through a regulator, thus allowing the superintendent to get some sleep at night, provided the device works properly; otherwise he may be worse off than before it was put in.

A considerable difference of opinion exists among water-works men as to the usefulness of pressure-reducing devices; some condemn them entirely and others are in favor of them. This

probably results from the different experiences they have had, some, perhaps, having employed apparatus unsuited to the conditions or not properly installed and cared for, others having been more fortunate in apparatus or conditions.

A pressure regulator is an automatic machine and cannot be treated merely as a part of a water main. It requires intelligent care, periodical cleaning, and should be suited to the conditions under which it operates. Some makers of pressure reducers advertise them as suitable for steam, air or water; in reality, the conditions under which a regulator works in a water-works system are so different from those obtaining in steam or compressed air practice that the apparatus for handling water should be quite different from that employed for steam or air.

A brief description of some of the most commonly used makes of pressure regulators may prove of interest.

The Ross regulating valve (Fig. 1) is made by the Ross Valve Company, of Troy, N. Y. The working parts of this valve consist of a central stem carrying the pistons E and F, and a disk valve G, which seats by moving upward and is sealed by the action of a leather collar. The areas of piston F and valve G are equal, thus balancing the inlet or high pressure and preventing a tendency to move up or down. A small reducing pressure valve B is placed on a pipe leading from the inlet side to the pressure chamber formed between pistons E and F. A relief valve C is on the pipe from the pressure chamber to the outlet side. The small gate valves A and D are for convenience in shutting off the water, and have nothing to do with the operation of the regulator, which is controlled by the action of the small regulator B and the relief valve C, which determine the pressure in the controlling chamber between pistons E and F. This pressure is intermediate between the high or inlet pressure and that carried on the low or outlet side, and is sufficient to balance the upward thrust of the low pressure water on the bottom of the piston G, when the pressure on the delivery side has reached the desired point. On account of the tendency to rise, caused by the top of the piston E being open to the air, thus partly counterbalancing the downward pressure on piston F, it is necessary to have the pressure in the controlling chamber higher than the delivery pressure, the amount

of excess being determined by the relation of the areas of pistons E and F. If the desired outlet pressure is exceeded, the upward thrust under piston G causes an increase of pressure in the controlling chamber; this closes or diminishes the flow through the

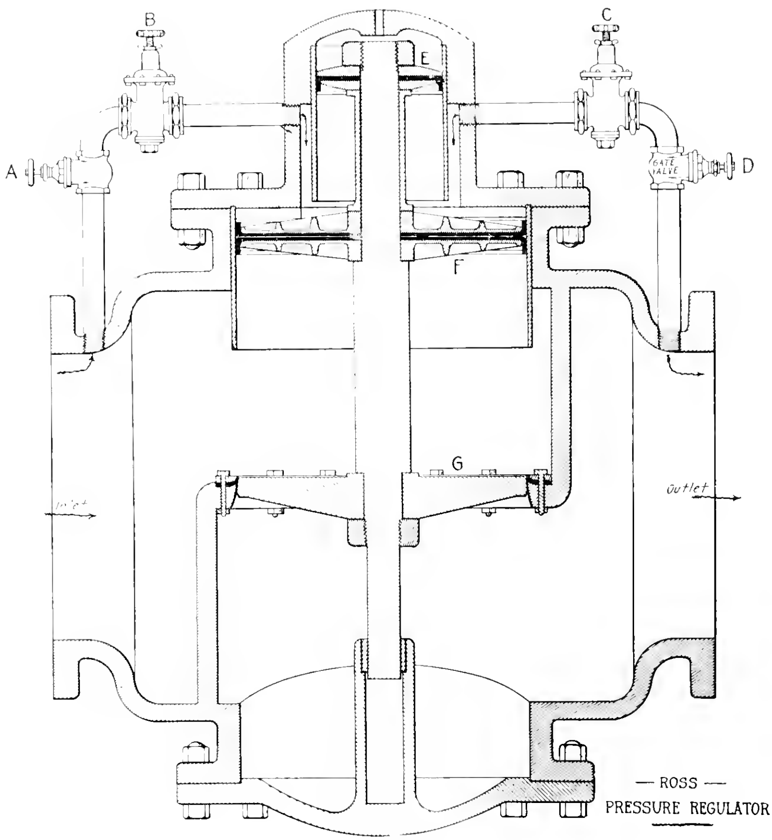


FIG. 1.

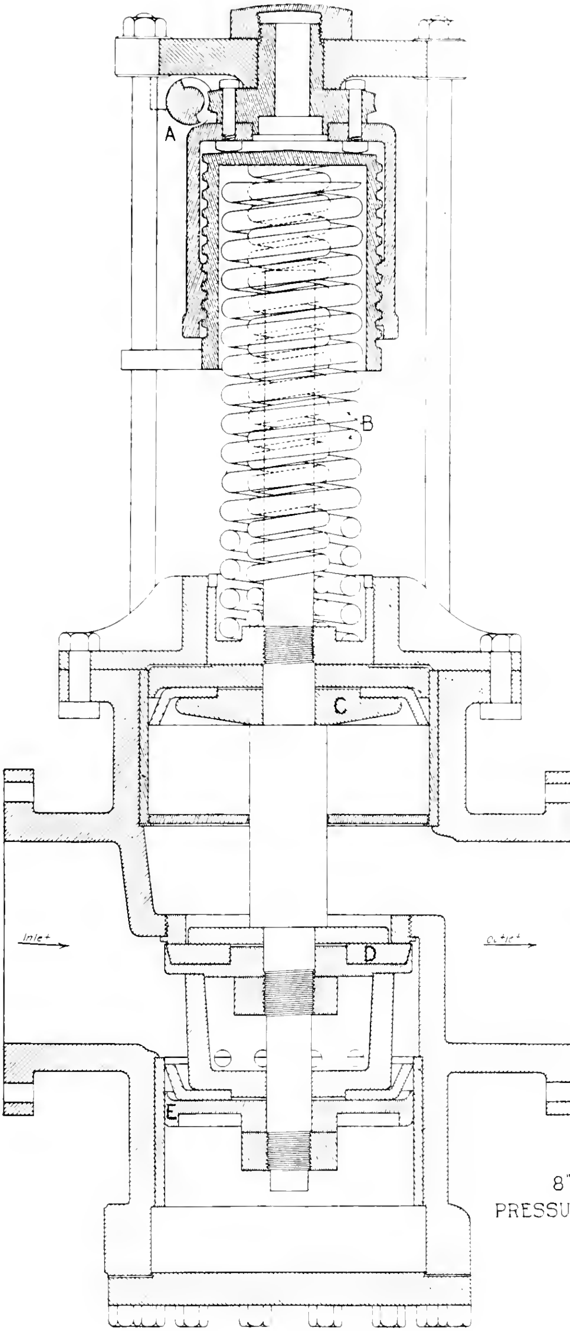
small regulator B and opens the relief valve C, allowing the pistons to rise and close the valve. When the outlet pressure falls, the pressure in the chamber is reduced, the regulating valve opens and the relief valve closes, allowing the pistons to fall, thus opening the valve and increasing the pressure on the delivery side.

The regulator is adjusted by turning the hand wheels on valves B and C, thus changing the pressure at which they will open and close. They are set so that the regulating valve B will close at as nearly as possible the same pressure that causes the relief valve C to open.

When this regulator is properly adjusted it gives close regulation and works well for long periods. It gives the most satisfactory service where the inlet pressure is fairly constant. From the principle on which it operates, it will be seen that if there is a considerable variation of the high pressure, especially if the minimum approaches closely or even falls below the low pressure for which the valve is adjusted, it will close, as the pressure in the controlling chamber is not sufficient to hold the valve away from its seat. This check-valve action is sometimes advantageous in cases where the valve is controlling the supply to a reservoir or standpipe, as, if a serious break in the main on the high pressure side of the regulator occurs, the valve promptly closes and prevents the loss of the stored water. But under ordinary circumstances this action results in a reduction of pressure on the delivery side below that desired. The cases where so little difference between the high and low pressure exists are probably exceptional, as ordinarily where a regulator is installed, there is quite a large difference between the inlet and the outlet pressures at all times.

The Mueller water pressure regulator (Fig. 2) is governed by a spring B, which is compressed by the pressure of the water on the delivery side acting on a piston C fitted with a rubber cup to prevent leakage. The valve D, on the same stem with piston C, is of the single-disk type, balanced by the piston E and fitted with a rubber face to make a tight joint. It is held away from its seat by the spring, until the pressure of water acting under the piston C is sufficient to compress the spring and close the valve. When the pressure falls, the spring forces the piston down and opens the valve. In the larger valves the area of the top piston is so great that very heavy springs are necessary, and a worm gear with hand wheel is used in regulating the tension of the spring.

The Union water pressure regulator (Fig. 3) is controlled by the pressure of the water on the outlet side of the valve acting under a diaphragm. This pressure is balanced when the desired



8" MUELLER
PRESSURE REGULATOR

Fig. 2.

point is reached by means of a lever and weights acting on the upper side of the diaphragm. The lever arm is connected to the stem of the valve and rotates the interior valve, which is in effect a large hollow plug cock having several ports connecting the inlet and the outlet sides. These are opened or closed as the pressure on the diaphragm diminishes or increases. The regulator is adjusted by varying the weights on the lever.

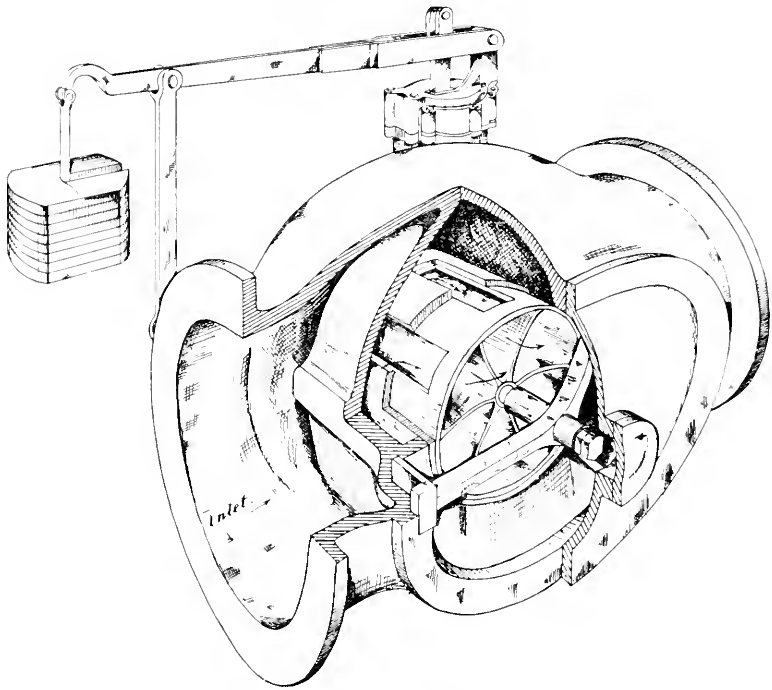


FIG. 3. 16-INCH UNION PRESSURE REGULATOR.

METROPOLITAN WATER WORKS REGULATORS.

Four regulating valves, three 8-inch and one 10-inch, constructed under the supervision of the writer, and embodying some features which are the result of a study of the operation of regulators under the conditions obtaining in the Metropolitan district, have been in service for periods ranging from two and one-half years to seven months, controlling the water pressure in various

parts of the Metropolitan district in a satisfactory manner. These valves, as shown in Fig. 4 and Plate I, are of the lever and weight type; the valve bodies are of the regular pattern of balanced valve made by the Waters Governor Company. The valves themselves are of the piston double-seat type; the pistons are connected by a cylinder instead of the usual rod, and are cylin-

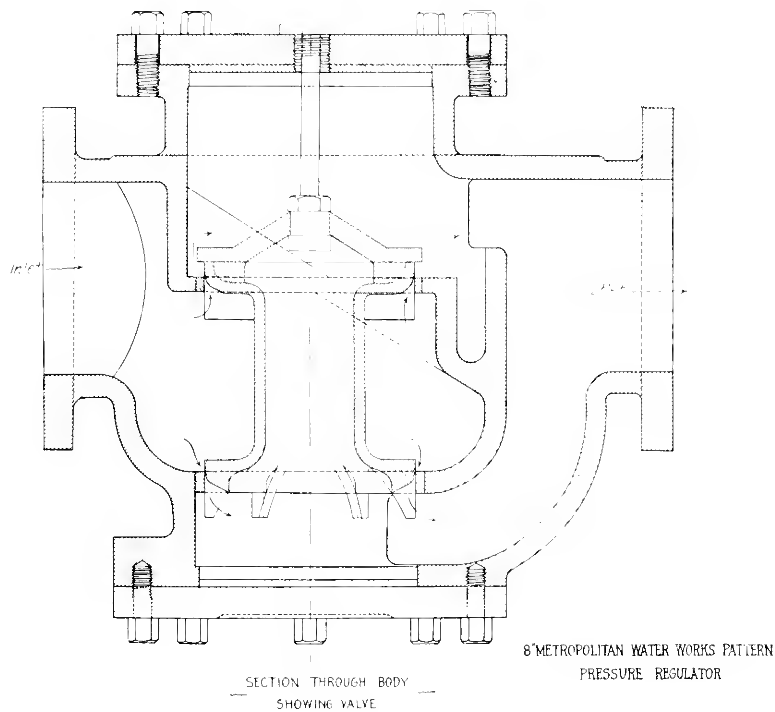


FIG. 4.

drical in section for $\frac{3}{8}$-inch below the top, then conical for another $\frac{3}{8}$-inch, and the bottom edges are rounded off. The object of this is to produce a considerable travel for small variations in the normal flow, which is small compared with the maximum capacity of the valve, and by a slightly greater lift to provide for large flow, as in case of fire.

The controller is a cylinder attached to the side of the valve body, containing a piston under which the water pressure on the delivery side acts; this is counterbalanced by the lever and weight. One end of the lever is attached to the stem of the balanced valve. When the outlet pressure rises the piston is raised, thus causing the valve to close. When the pressure falls below the desired point the weights cause the valve to open. By adjusting the weights a large range of pressure may be obtained. The controller is constructed so that a variable speed is obtained; when the valve is a considerable distance from its seat, water has free access to the controlling cylinder and the motion is comparatively rapid, but as the valve approaches its seat the admission of water under the piston is gradually checked and the speed reduced until the last part of the closing is done very slowly. The controller piston is attached to the lever in such a way that its travel is considerably longer than that of the main valve.

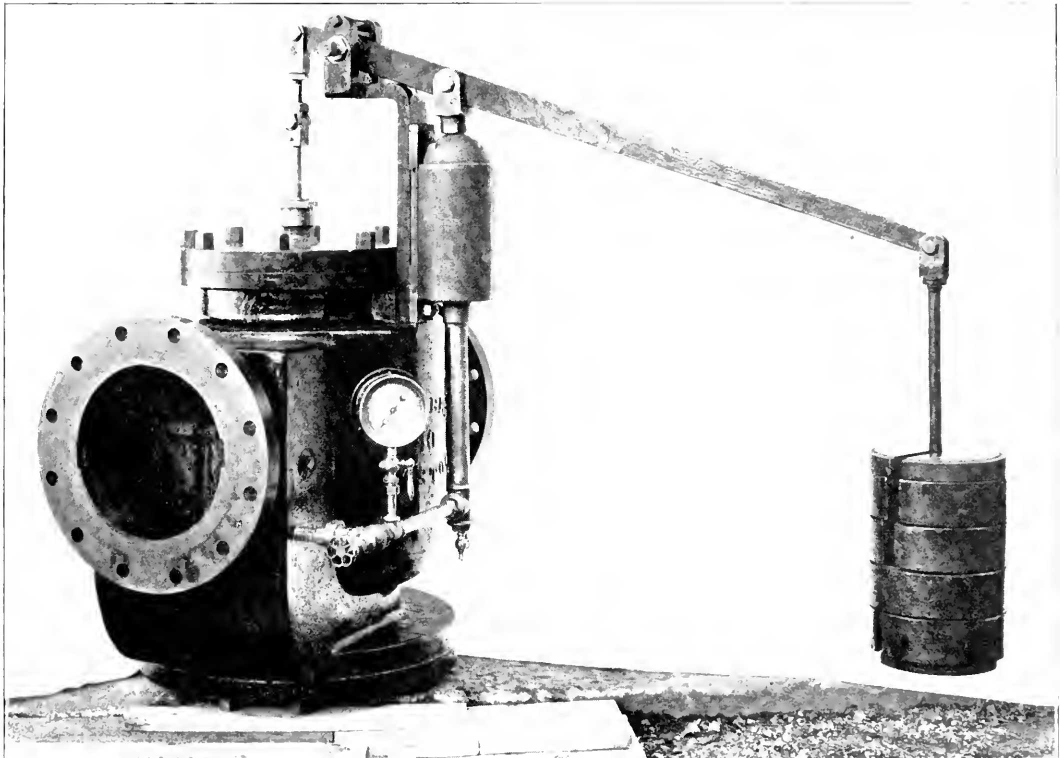
The device is practically a dashpot and controller combined, and this, together with the conical form of the upper part of the main piston valves, reduces the danger from water ram caused by sudden closing of the valve to a minimum, and prevents surging.

Particular attention was paid to having all parts easy of access. The main valve is quickly removed by taking off the top head and drawing it out through the seat rings without disturbing the lever, controller, or weights. All parts liable to corrode and stick are made of composition.

It is impossible to make a piston valve absolutely tight and have it remain so, but the leakage is so small that it is generally much less than the leakage from the water mains and fixtures supplied through the valve.

In order to give the most satisfactory service under the rather trying conditions met with in a water-works system, a pressure regulator should be simple in design, having as few parts as possible, and free from delicate mechanism. It should be strong, durable, and reliable, having all parts easy of access from the top, without the use of special tools. All parts liable to rust and thus interfere with the proper working of the apparatus should be made of composition or other non-corrosive metal.

PLATE I.



EIGHT-INCH METROPOLITAN WATER WORKS PRESSURE REGULATOR.

The regulator should not, under any conditions, close suddenly, thus causing a dangerous water ram in the pipe on the high pressure side. It should not surge, thereby causing an intermittent pressure on the mains. The apparatus should be controlled entirely from the low-pressure side; and variations of pressure on the inlet side, within reasonable limits, should not affect the pressure on the delivery side. The valve should be balanced as nearly as possible and should not be liable to stick in its seat.

The sensitiveness should be suited to the requirements of the particular conditions under which it is to operate; for instance, a regulator supplying a system of mains connected with a reservoir or standpipe should work within closer limits than one serving a pipe system without such outlet, as in the former case the reservoir is liable to overflow and cause damage if too great a variation in pressure is allowed; while a considerable range of pressure would not ordinarily make any material difference in a closed system of pipes unless it is a case of weak mains, when close regulation would be desirable.

As there is always more or less fluctuation in pressure in a water main, especially during the time of maximum flow, a regulator which is too sensitve is constantly in motion and suffers excessive wear, besides having greater liability to surging and producing water ram. Under ordinary conditions a valve that will operate on a change of pressure of from two to four pounds should give satisfactory service.

If for any reason extreme sensitiveness should be required, a small auxiliary valve, nearly frictionless, operated by a diaphragm of large area, may be employed to control a hydraulic cylinder which moves the main valve in much the same way that a damper regulator is operated.

It is a common practice to install a regulator of the same size or even larger than the pipe line in which it is set. Under certain conditions a valve which is too large for its work is liable to give unsatisfactory results. As the regulator operates by throttling the opening through which the water passes, it follows that when the consumption is very small the valve is very near its seat and any sudden rise in pressure on the delivery side will be apt to shut the valve entirely, thus producing a water hammer

which is liable to break the pipe above the regulator. The valve and seats are more liable to damage from the cutting action of the water at high velocity in a large regulator with a small flow than in a smaller valve handling the same amount of water. The pressure regulator should be only large enough to pass the maximum flow of water likely to be needed in the district supplied through the valve without excessive loss of pressure on the delivery side. The friction loss due to the maximum flow in the pipe line above the valve should be taken into account in any calculations of capacity. In general, a valve one or even two sizes smaller than the pipe line will be found amply large.

A pressure regulator should always be set in a chamber, preferably built of brick, sufficiently large to allow the valve to be taken apart without difficulty. If set in the pipe line, a by-pass containing a gate valve should be built around the regulator, or it may be set in a by-pass with a gate in the main line between the by-pass connections. In order to facilitate examinations or repairs, it is advisable to have a stop valve on each side of the regulator; by closing these and opening the by-pass valve the proper amount, the apparatus may be taken apart without interrupting the service.

In order to keep track of the pressure on the delivery side while the regulator is out of service, a gage cock may be put in the pipe beyond the stop valve on the outlet side. By attaching a gage to this the pressure may be watched, and any regulating necessary may be done by opening or closing the by-pass valve by hand.

In cases where there is a liability of sand or gravel being carried along with the water, it is a good plan to install a sand catcher just above the regulator. No screen should be used, as it would be liable to become clogged and thus cut off the flow.

In choosing a location for the regulator it is advisable to place it at such an elevation that the pressure on the outlet side will be as light as possible, as this avoids excessive loading by weights or springs in the case of regulators controlled by these devices. The valve should not, however, be located at a summit in the pipe line, as air would be liable to collect in it and perhaps interfere with the operation of the regulator.

In cases where considerable damage would be caused by a pressure exceeding that for which the regulator is adjusted, a water relief valve may be placed on the pipe beyond the regulator, and a connection made to a drain or brook.

It would be advisable to inspect such a relief valve occasionally in order to detect any leakage.

A battery of regulators is sometimes installed to handle a very large flow of water. If the regulators are set so that one will handle the light flow and the others come in as the pressure falls, owing to increased consumption on the low-pressure side, the danger from the sudden fluctuations of pressure and the cutting of valve seats is decreased. On the other hand, if the large flows only occur occasionally, as, for instance, during large fires, the regulators set to open last may stick in their seats and refuse to work at a critical moment.

In conclusion, it may be said that if a regulator suited to the conditions is selected, properly installed, and given inteligent care, it will be found a perfectly practical and satisfactory apparatus.

DISCUSSION.

The President. The paper is before you for discussion. I will call first upon Mr. Ross.

Mr. William Ross.* I did not come here prepared to discuss this paper; in fact, I was under the impression that associates were not expected to say anything except in a quiet way to the members. I will not take up much of your time, therefore, although I am much obliged to you for calling upon me.

Mr. Doane has given a very good description of our valve, but there were one or two things, one in particular in reference to the difference of areas, to which I should like to call attention. This can be varied, and the area can be reduced so you can get a full flow of water, the capacity of the pipe line, through the valve, with a reduction of not more than one and one-half to five pounds, depending somewhat upon the size of the valve. On a very large valve we can reduce the area exposed to the atmosphere so that we can deliver the capacity of the pipe line through the valve with only a difference of a pound and a half. I don't believe it wise

* Secretary, Ross Valve Company, Troy, N. Y.

to go as close as that, because the valve must be very sensitive if it works on so little variation of pressure.

MR. FRANK L. NORTHROP. I should like to ask Mr. Doane if the pressure on the high-pressure side, the variation of pressure, makes any difference with this new Metropolitan valve?

MR. DOANE. So far as I have been able to find out it does not until the high pressure approaches very nearly to the low pressure, that is, until it gets practically way down, and then the only trouble is apparently due to friction through the valve. We have had a chance to try that on several occasions, and so far as I have been able to find out it is not affected; and it is rather hard to see how it would be affected, for the reason that the controller is connected with the low-pressure side and has absolutely no connection with the high-pressure water.

MR. NORTHROP. There is quite an amount of friction, then?

MR. DOANE. In all these disk valves there is considerable more friction than there would be in an open-gate valve but the idea of the thing is to produce friction. You want to reduce the pressure, and in order to do that you put in a frictional device really. That is to say, it throttles the water and that produces friction, and that cuts down the pressure; the object is to keep the pressure down. When you want to get a large flow you have to have area enough to pass that flow without an excessive loss of pressure, as I said in the paper. And, if you will notice, this is a double-disk valve, so it has a pretty good area when both disks are on the same spindle. There are really two openings, and the area is considerably greater when they are wide open than the area of the outlet pipe.

MR. NORTHROP. Of course with the Union valve, where it is controlled on the low side, the same is true, only our friction is divided. We have no friction against the plunger.

MR. DOANE. There is but little mechanical friction in our valve. I thought you meant liquid friction. There is practically no friction in this valve except the friction of the stuffing-box, which isn't very great, that is, unless somebody is too strong with the monkey-wrench on the stuffing-box.

MR. EDWIN C. BROOKS.* Mr. President, I think I owe it to

* Superintendent of Water Works, Cambridge, Mass.

the Ross valve to say that the city of Cambridge has two 16-inch Ross regulators on a 40-inch steel main. That, you will see, is cutting down the area very much more than anything which has been spoken of here; the ratio would be somewhere about 512 to 1 600, less than one third. Those valves have been in use now about eight years. We have four Bridgeport recording gages installed in different parts of the city, from which we take weekly charts, and the valves have certainly performed remarkably good work. I suppose they are in the pit where they were the last time I looked for them, but as far as any knowledge of that is concerned, I don't know really that they are there. The regulation is very close, and the valves have given no trouble, excepting that we had, on one of the small regulating valves, a spring break, four or five years ago. I never have had to have the valves even taken apart since they were put in there.

The President. Mr. Coffin, have you had any trouble with these valves?

Mr. Freeman C. Coffin. I am sorry to say I never had anything else. I ought to say, however, that I have never used but one of the valves, and therefore my experience is not conclusive.

Mr. John C. Whitney. I think it would be interesting if Mr. Coffin would tell us about some of his troubles.

Mr. Coffin. It was very simple, Mr. President. The valve didn't keep in order. It seemed to be impossible, with the pressure which was on it — it was a small valve, only 4-inch — to keep it in working order, and the result was that after being repaired several times it was abandoned. About all I can say is that it failed to do what I put it in for.

Mr. F. I. Winslow. I should like to know something about the cost of such a regulator.

Mr. Doane. I should think an 8-inch valve would perhaps cost something under $300, all complete.

Mr. Winslow. Including the by-pass and stop valve?

Mr. Doane. Yes.

Mr. Ross. I should say that to install a 12-inch with a by-pass would cost about $450. That includes the gate valves, two bends, two nipples, and the regulating valve.

Mr. Charles N. Taylor.* I never had any experience with large valves, but I want to say a word about the small valves in service pipes. I have had a great deal of trouble in my house at Wellesley, where we have seventy to eighty pounds pressure, in keeping my ball-cock valves from leaking, and every little while I would have to send for a plumber, which was very nice for the plumber, but rather bad for me. I was telling my trouble to a supply man one day and he said, "I can fix you all right." So it was but a few days before I received a 1-inch Mueller reducing valve. I didn't have much confidence in it, but I thought, as long as they sent it to me, I would have it put on, and I did. That was about a year ago. I had it set so that it reduced the pressure to about forty pounds, and it has given me great satisfaction, and I have been relieved from having the plumber come so often as he used to. I should recommend putting in one of these valves wherever there is trouble such as I had. I think the cost is something like $3. Mr. Ross shakes his head and says that that is low. I didn't pay for it, and so I can't tell the cost, but if it cost $5 or $10, I think it would be economy to put one in.

Mr. George A. King.† I should like to confirm what the last speaker has said. I have had a Mueller valve on my service pipe for five years and it has given great satisfaction. We have direct pressure, and are liable to raise the pressure from forty-five pounds to one hundred pounds.

The President. I should like to call upon Mr. Caldwell.

Mr. George A. Caldwell.‡ I thank you for calling on me, Mr. President, but I don't know that I have very much to say about our regulators, except that I can give you the price. For 1-inch, it would be somewhere, as I remember it, in the neighborhood of $5 to a plumber or water-works man. For ½-inch, the price is $3.75. We make the claim for the Mueller regulator that we hold the pressure at the set pressure. For instance, if we set the pressure at forty pounds, we will hold it within three pounds of that right along in service. A great many pressure regulators are merely check valves, which reduce the pressure while the

* Civil Engineer, Wellesley, Mass.
† Superintendent of Water Works, Taunton, Mass.
‡ Representing H. Mueller Mfg. Co., Decatur, Ill.

water is flowing through the valves, and after the pressure has arrived on the outlet side to the set pressure, then there is a certain amount of leakage through the regulator, which will in time bring the pressure on the outlet side up to the normal pressure of the service. This we claim is not possible in the Mueller regulator. I cannot say much about the other regulators, for I haven't made any extended observations in regard to them, and therefore I am not in a position to speak about them.

I should like to ask one question. In a direct pumping system, will the Metropolitan regulator hold the pressure at the set pressure as well as it will in a gravity system?

MR. DOANE. We have a case of that kind where the fluctuations in the pump are very marked on a gage put on the high-pressure side of the regulator, and I have never been able to see that it affected the regulator in any way. It might carry slight pulsations through it, when the regulator was open considerably, but not enough to amount to anything.

A good use for pressure regulators on direct pumping systems is to put them on the service pipes, because the way they are operated in many cases, as I understand, is to raise the pressure to one hundred pounds or over when they have a fire, to throw in more pumps and raise the pressure up to the fire pressure, and when there is no fire they reduce the pressure to what would be a good domestic pressure. In that case it brings a violent fluctuation on the service pipes, which is very liable to cause numerous and costly plumbers' bills, and if you have a small regulator, a Mueller or a Ross, or any standard type, on the service pipe, it will take care of that fluctuation and keep the pressure to a reasonable figure on the house side and avoid all destruction of the plumbing. These house regulators are a good thing, and I can speak from personal experience.

MR. CALDWELL. Just one more word with regard to that. It seems to me, with all due respect to every regulator on the market, the Mueller as well as the rest of them, that where you install a regulator on your main line for reducing the pressure, there is no regulator that will work satisfactorily unless you have a by-pass around it, so that in case of fire you can open up your by-pass and give your full pressure on your main. I don't think any

regulator will give you the full flow through and still hold your pressure down to the set pressure of your regulator.

MR. DOANE. That is so, of course, from the nature of the regulator. Otherwise it wouldn't work at all. But if you want to get a higher pressure, as you say, you have got to go and open the regulator, unless you have some automatic device which will open it, and even those automatic devices will still take up some pressure.

REPORT OF THE COMMITTEE ON PRIVATE FIRE SERVICES.

[*Presented December 13, 1905.*]

Gentlemen of the New England Water Works Association: At the 1902 convention of the American Water Works Association, a report was adopted, expressing the sentiment of the convention that a charge be made for fire protection; that unreasonably large services for fire or other purposes be not permitted; that meters be used where found necessary, and reasonable control secured of all large services.

The Central States Water Works Association, at a convention in 1902, unanimously adopted a resolution expressing the sentiment of the convention in favor of an equitable charge for the protection afforded by private fire services.

At the annual convention of 1903, this Association adopted a report recommending that a charge be made for fire protection; that unreasonably large services be not permitted; that meters be used where found necessary, and all large services provided with a cut-off or a gate so located as, under any ordinary combination of circumstances, to be readily accessible; action along the same lines as that of the American Association for the year previous.

At the 1905 convention of this Association, this committee was enlarged by the addition of Mr. Geo. W. Batchelder and Mr. Hugh McLean, and instructed to consider and report a method or methods by which the value of fire protection can be estimated.

In compliance with instructions, your committee report that fire protection should yield a revenue about in proportion to its cost, as compared with the entire cost of the work; that private fire protection may be estimated at some per cent. of the entire cost of fire protection, and apportioned among those benefited in proportion to the floor space of the protected risks. The cost of fire protection, like that of furnishing water, will vary in different

localities, as also the proportion properly chargeable to private fire protection, and this may be determined in and for each individual case. Floor space seems to your committee to be the unit bearing the closest relation to value of the risk and cost of protection, of any readily determined.

We would recommend that charges for fire protection be made on the above basis, with due regard to different conditions obtaining in different places.

Respectfully submitted,

F. H. CRANDALL,
R. J. THOMAS,
GEO. W. BATCHELDER,
ELBERT WHEELER,
Committee.

DISCUSSION.

The President. You hear the report of the committee; it is now before you for discussion. We should like to hear from Mr. Chase.

Mr. John C. Chase.* Mr. President, I do not know why you should single me out as the first to be called upon, unless it is because I was in such a woeful minority when this subject was threshed out by the original committee. I have seen no reason to change the views that I expressed then, that private fixtures installed by the consumer for additional fire protection should not be subject to an extra charge, as he was already paying for protection under the general tax levy, and his outlay was a benefit rather than a detriment to the water department, the most serious problem confronting them being to prevent the consumer from committing larceny. This view, however, seems to be a dead issue, and from what I have heard of Mr. Crandall's report, I think perhaps the committee have solved the problem in the most practicable manner, and that if a charge for private fire service is to be levied, as the prevailing sentiment seems to indicate it should be, it can be adjusted in no more equitable manner than that which the committee recommends. I think the committee, and also the Association, are to be congratulated upon the apparently successful outcome of their labors, and under the cir-

* Derry, N. H.

cumstances it is perhaps proper that I should be the one to now move that the report be accepted and its recommendations adopted. I do not know that I have anything further to say in relation to the matter, except to thank you for giving me the prominence of being the first one to be called upon, with a clear field and no chance of any one else having said what I wanted to say.

The President. We are all very sorry that a man who was as much interested in this subject as any man in Boston, Mr. Edward Atkinson, has passed away since we last met. I will call upon Mr. French to speak.

Mr. Edward V. French. Mr. President, I did not expect to be called on in this way. I do not know that there is much that I, or perhaps any one of us, can say with regard to Mr. Atkinson. We all knew him, we all have seen him here on a good many occasions and have been interested in what he has said, and we were always pleased with the vigor and constantly continuing interest which he had in all these subjects.

Mr. Atkinson came down town on Monday in the usual way, but on reaching the office it was found that he was not able to get out of his carriage. Although every effort was made to give him help immediately, he died an hour or two afterwards, just after reaching the hospital. Mr. Atkinson was about seventy-nine years of age, and, as we all know, lived a most vigorous and energetic life, always working, always busy, always having many interests. I think it is an inspiration to come in contact with a man, whether we agree with what he thinks and with what he does or not, who is so thoroughly alive, and especially at Mr. Atkinson's age, towards all the important problems of the day.

The President. Mr. Hammond.

Mr. J. C. Hammond, Jr.* Mr. President, I am glad that the mantle of Elijah has fallen on so good shoulders. We certainly have a very able Elisha in the insurance host.

I came here some years ago trying to find out what was a fair charge for fire service, in view of the greatly increased cost for mains over and above the necessary cost for domestic supply

* Treasurer, Water Company, Rockville, Conn.

alone. I simply asked what would be a fair charge for the fire service, and I was so thoroughly convinced (?) by the arguments I heard from the insurance people that we couldn't charge anything, that I went home and said to our livery man, "Send the team over to the office every morning; if we use it we will pay for it, if we don't, we won't." [Laughter.]

THE PRESIDENT. I should like to call upon Mr. French.

MR. FRENCH. Mr. President, again I am hardly ready to say very much. I think Mr. Hammond's story is too good to try to spoil any of the influence of it right away. It is some little time since we have given this question of charging for water very much attention. In the last few years our efforts have been mainly directed toward preventing the improper use of water. I felt after the experience on the previous committee that if we could put the fire service into such condition that it would be properly used, a good deal of our present difficulty and the feeling of suspicion about it would disappear.

Now this question of charging for fire service is a difficult one. It brings up all the general questions of methods of taxation, and in trying to go into it, and in working a considerable time on it in connection with the committee, when Mr. Hammond and I were together, I found it extremely difficult to find any very satisfactory method of charging. To go back a bit, I have not really had an opportunity to consider exactly how this report would work out, but I should think it would be better than the method of charging so much per sprinkler or so much per hydrant, which has the effect of making a man very reluctant to add a sprinkler here or there in places where sprinklers are needed.

One other point is that in the case of almost all other commodities we pay for what we get; and I tried to work out some sort of a plan by which a man would pay so much per fire stream available at his yard as serviceable pressure. Now on the basis just proposed, if in a city or town there were two plants of the same floor area and about the same value, and one of them was in one end of the city, perhaps near the reservoir, the owner might be able to draw eight fire streams from a connection, which we would all be willing he should have, into his yard. The other manufacturer, at the other end of the town, but just as much within the limits of

the town, perhaps no further from the city hall, might not be able to get more than three or four streams, on account of the fact that he was farther away from the reservoir. Now, by this method of charging, you charge both men the same, while one man would be getting twice as much as the other.

Of course, I realize that all these things are matters of compromise, that we have got to strike on some workable scheme, but it isn't exactly fair to charge on that basis, when a man doesn't get what he pays for, so to speak. Perhaps there is no better way to do it and I am not ready to criticise, but simply want to bring out all sides of the question.

Another point: it is true that the man who puts in private protection does get a saving in the cost of insurance. He gets it by spending usually from three to five per cent. of the value of his property, in putting in automatic sprinklers, fire pumps and hydrants. Now that man, if he hadn't put in that private equipment, would clearly have been entitled to the use of the entire fire department of the city. If his plant had gotten on fire, no man would have thought of charging him anything for the services of the fire department. I know I have said this before, but it may be well to repeat it. If he puts in his private fire protection the chance of his having a fire which will necessitate his calling upon the public department is very small. Our experience shows that in 90 per cent. of the cases the opening of five or ten sprinklers puts out the fire. Those fires, had they been allowed to go on for any length of time, would undoubtedly in many cases have become larger.

Going further, the risk, if unprotected, may be a serious menace to surrounding property. I think nobody questions that if the building in which the Baltimore fire started had been sprinklered it would not have burned as it did, and the Baltimore conflagration would not have occurred. If the owner or occupant of that building had put in automatic sprinklers at his own expense, he would have saved the community an enormous amount of money. And the one point that I want to make clear is that there is a very distinct gain to the community from private protection. There is a gain to the owner, nobody denies that, but there is also a very distinct gain to the community; and, perhaps, if we look at it in

all its lights, we will realize that it may be the highest type of public policy to encourage private fire protection.

I should say that if the water for fire protection of a city were paid for by the general tax levy, as is true in some cases, — while in other cases it is paid for simply from the water department's funds, — it would seem that any taxpayer had the same right over it that any other taxpayer had, and that the better facilities he provided at his own expense to use the public water which is there for this purpose, why, really, the more he was doing for the common good. I hope then that we will not lose sight of the fact that a great advance is being made in cutting down the annual fire loss in this country, amounting to $150 000 000 on the average for ten years past, — or, if not cutting it down, at least in preventing it growing larger as our country grows, — by the use of private fire protection. This certainly is the case, and it ought to be a factor in any action taken by public servants looking at it from the point of good citizenship.

Mr. Charles W. Sherman.* Mr. President, if the force of all Mr. French's arguments is granted, and they certainly have a great deal of force, the fact nevertheless remains that at the present time the cost of fire protection furnished by a private water company is not at all borne by the municipality, excepting in so far as it pays hydrant rental, and in that way, as a rule, no portion of the cost of private fire protection is covered. This question was first raised, at least in this association, in connection with private companies, and perhaps its most important bearing at the present time is to furnish a basis for private companies to make such a charge, more so than in the case of municipally owned plants; and in that direction especially the report of the committee, it seems to me, is going to be of great value. I think Mr. French will concede the desirability of something of that sort in connection with private companies, even though his principle that in equity such a charge ought to be borne by the municipality should stand.

Mr. Charles K. Walker.† The other day a man said that he wanted fire protection for a barn, which they use for storing cars

* Civil Engineer, Boston, Mass.

† Superintendent of Water Works, Manchester, N. H.

in; their car barn had burnt up. They wanted to know what I would do about it. I told them I wouldn't do anything about it if I could have my say, but I can't have my say.

Now they wanted a pipe put into this car barn. They wanted a 6-inch pipe on one end — it is about 200 feet long — and they wanted a 6-inch pipe on the other end. And then, by the way, they wanted a pipe to another car barn on the opposite side of the street. They wanted a 14-inch pipe tapped and two 6-inch pipes on one side and one 6-inch pipe on the other side; and there was no other way to do than as the commissioners told me, and the commissioners did just what the insurance underwriters told them to do. The result was that we put those pipes in. I objected to it. We don't get a cent out of it. Perhaps they will pay for the connection, but they won't pay anything for supplying water to these places. I say it is all wrong. I say that these insurance folks ask too much. I think we ought to have compensation for furnishing water to these places; a small amount, perhaps, but we ought to have something for keeping up these supplies; and I think it is the duty of every city to charge for the supply of these places with water in case of fire.

Mr. Hammond. Right in that line, Mr. President, I would say that we have two 8-inch and one 6-inch connection on a 10-inch main, as fire protection for a manufacturing plant. Abraham Lincoln used to tell of a steamboat on the Mississippi with a 100 horse-power engine and a 200 horse-power whistle, and every time they blew the whistle the boat stopped. Now, I don't think it is good policy, if you have other property on the line, to jeopardize the whole thing for any one concern. A man who makes tanks out West sends out his circulars and tells his customers that if they will *buy* a tank and put in sprinklers he will guarantee that they will get the cost back in five years in the saving in insurance. Now, I think there are two sides to this question. The insurance people shouldn't come in here and say that we should furnish free water, while at the same time they say to the manufacturers, "Our companies will only charge you a quarter of one per cent. for insurance with sprinklers, which you couldn't get in the stock companies short of 2½." Am I not right? Still they say that there should be no charge for water if the insured don't use

it. It is there for them to use if they want to use it, and when they pay for their insurance they pay the low rate because it is there.

MR. FRANK C. KIMBALL.* I remember attending a convention of this association in September, 1902, when I believe there were three reports made on this subject. It appeared very conclusively at that meeting and by those reports that the water-works superintendents and the underwriters couldn't lie down in the same bed together.

As a result of that meeting the Private Fire Protection Committee, which has reported to-day, was appointed. Whether it has been due to the work of that committee, or to an increased sentiment along these lines, or to some other good reason, I am very glad to note to-day that Mr. Crandall again reports for that committee, stating among other things that fire protection should be paid for, and Mr. French now gets up and says: " Pay for what you get." In other words, he agrees with Mr. Crandall to-day, whereas he didn't three years ago, under the principle, as he states it, " Pay for what you get." Nobody who gets fire protection would for a moment say that he is not getting something.

I was very glad also to note last September that, while that portion of the committee of 1902, of which Mr. French was a member, reported against metering fire connections, Mr. French himself gave us a very good illustration of how a person can be converted at times and also showed us the results of his conversion in a meter which I for one am free to say comes very close to filling the bill; if it is not exactly what the water-works men themselves are after it is so near it that a company I am interested in is going to try one of them and see how it works, and I think before we get through we shall try several.

It seems to me that this question now has got beyond any discussion. The underwriters agree that protection from petty larceny or grand larceny is necessary for the water companies or water departments. They also agree that something should be paid. That is as far, I think, as we can ask them to go. And I think that they will agree with me when I say that it is not within their province to say what that something shall be. Mr. French

* Civil Engineer, Boston, Mass.

says, "Pay for what you get," and that a price which would be adequate in certain parts of a town might not be adequate in another part. Unfortunately you can pick flaws in any schedule or plan for anything that may be offered. It may also be unfortunate for them, although perhaps fortunate for the public, that water-works superintendents and departments are to some extent controlled by the courts, which say that you shall not discriminate. They do not look at these points quite so finely as the underwriters do, and when you charge a man in one part of the town one price and charge a man in another part of the town another price, they say that is discrimination.

I have perhaps given this question of charges for fire protection as much consideration as the average member here, and in going over the possible methods of charging for protection, the one that seems to me to be open to the least objection is that of charging by floor space. Floor space bears some relation to the value of the property,— the larger its area the more valuable. It also bears a distinct relation to the space to be protected; the larger area means, to some considerable extent, larger pipes. Now, you can reason this thing in a complete circle. Fire protection should be paid for. When you pay for fire protection you should get what you pay for. In that way, paying for fire protection you have a right to ask for that protection. You are obliged to put into your works larger pipes, larger pumps, etc., and, as Mr. French said a few moments ago, while in your general tax levy the hydrants along the public streets are paid for, I think he will say that hydrants every 300, 400, or 500 feet, as they usually are along the public streets, are not adequate protection to his mills, thoroughly equipped with sprinklers and yard hydrants, where in a space of 500 feet, perhaps, he would require 6, 8, or 10 yard hydrants and innumerable sprinklers. I don't blame him; I would if I were in his place, and it may be it is necessary for the proper protection of the property. But mains which will adequately supply hydrants placed every 300, 400, or 500 feet apart, are not adequate, nor will the underwriters accept, with their minimum insurance rates, the same sized mains for the protection of their mills, supplied as above. The result is that if you are going to furnish such mill owners with *proper* protection,

the first thing the water department has to do is to reinforce its mains, either by running a larger pipe along the street or bringing in connecting pipes across and around from other directions. So I think the argument that private fire protection costs nothing, or that it only costs what public fire protection does, was settled — it certainly was in my mind — long ago.

MR. FRENCH. Mr. President, if I may take a minute more, I just want to set myself right on one or two points. In regard to what Mr. Hammond says, I think it wasn't quite fair for him to suggest that I came here saying that there should be no charge made. I said nothing of the kind. And in regard to what Mr. Kimball said, I would make a slight correction, for neither did I say that I was ready to agree that charges should be made in all cases. I simply said that I hadn't considered the matter for some little time in detail, and I only tried to bring out a few additional points.

I realize that it is a complicated question. I realize that in some ways it is a question about which we should say nothing, perhaps; but I think we can at least properly bring out some points on the other side, for it is always fair to show up both sides of a question. In the main my argument would be that whatever charge is made, if any is made, should be equitable. You shouldn't single out the few men whom you can most easily find and charge them for fire protection because they have spent their own money for apparatus so as to be better able to use the public water service, while you do not charge other people, who have the same service standing ready for them, like Mr. Hammond's hack at the door, ready for them to use whenever they want it. You certainly should not charge them, I will put it in this way, more than you charge other men who simply depend on what the city may furnish them.

Now I should like to throw out one other thought. Take it in Mr. Hammond's excellently protected town; I should like to know who pays for the water and who pays for the service which is rendered to the unprotected property? If some night an unprotected building takes fire and the public fire department throws twelve streams for five hours, the owner certainly has the use of the public service and the use of a good deal of water; but I haven't

heard anybody say much about who should pay for that. When the water works are owned by a private company, we all agree that the company should be paid in some way. When the supply is merely a department of the city, having its own books and its own accounts and no other money, then it is perhaps entirely proper that from some source, say the general tax levy, or from the fire department appropriation, or from somewhere, it should get some return for the somewhat larger pipes, perhaps larger pumps and larger reservoir. I think we would all agree that fire service increases the cost of the public water works in many places, especially in the smaller ones. Now somebody ought to pay for that, but not simply the few men whom we are singling out to-day.

I would like to leave the matter in this way: That my own mind is open. The companies with which I am connected certainly do not want to ask anything unreasonable. I do not come here with any such intention. We would merely like to present these other points to show that the question is not a perfectly simple one, and to urge that whatever is done shall be done on an equitable basis and with due regard to all the factors in the case, and with proper encouragement of things which are a real benefit to the community. With more time for thought, we might have something more definite to suggest, but that is our position to-day. It is simply a plea for fairness and a plea for a broad view of the whole situation.

Mr. Hammond. It is said that early impressions are lasting. Perhaps my words didn't convey my idea, but I think the insurance men have been coming up here for about three years. In the early stages of this discussion, as I understood from Mr. Atkinson, a gentleman whom we all revered, these manufacturing concerns were a part and parcel of us, we were dependent upon them entirely, and we should protect them without any charge. Now, in my town, our manufacturers do not ask for that. What started this thing with me three years ago was to see how we could get at a fair charge, and I advocated then, as I advocate now, that it should be on the basis of the amount of insurance. We have a concern which makes envelopes, where several thousand feet of floor space is occupied by paper boxes, while in another establishment, where they manufacture silk, almost all the floor space is

occupied by valuable machinery. It isn't fair to tax them according to floor space, but it seems to me it is fair to charge them according to the amount of insurance carried, for the saving in insurance is something wonderful. One of the most beneficent things of the age is the development of fire protection appliances. Fires occur now which we don't know anything about until they are extinguished, and it is a grand thing; but the people who furnish the water should have some compensation, and the manufacturers in our place are willing to pay it. The simple question is, What is a fair basis to put it on? Now, what is fairer than to say that if one concern carries $100 000 insurance it shall be a certain percentage on that, while another concern, having more valuable machinery and carrying $500 000 insurance should pay on that basis? It isn't a question of our robbing them or of their robbing us. That question hasn't been raised. But when we ask what is a fair basis to put it on, we don't like to be told that they shouldn't pay anything.

Mr. Horace G. Holden.* At our New York meeting, last September, I made inquiries among the members to find out if there was any place where they made any charge for fire service, and from what I could learn there wasn't a place in New England where any charge is made. I talked with several of our western members and found that through the West in many places they did make a charge, and I have had some correspondence since in regard to the charges. Perhaps it will be interesting if I read to you what their charges are. This is from the office of the Louisville Water Company, Louisville, Ky., which is partly a private and partly a public company — I think the city owns some of the stock.

"At a meeting of the Board of Directors of the Louisville Water Company, held December 23, 1898, the following amended rules and rates for fire protection service water pipes were adopted, viz.:

"'1. That the water company locate and place all special private service connections for fire protection and automatic sprinkling devices from street mains to the property line of property owners and maintain same at the cost of the company.

"'2. That the annual rates for such special private fire service connections, payable semi-annually, subject to the usual dis-

* Superintendent of Water Works, Nashua, N. H.

counts for prompt payment to water consumers, shall be as follows, to wit:

1-inch connections	\$6.00
$1\frac{1}{4}$-inch connections	8.00
$1\frac{1}{2}$-inch connections	10.00
2-inch connections	15.00
3-inch connections	20.00
4-inch connections	30.00
6-inch connections	50.00

" 'If the above rates be not paid under the rules and regulations of the company governing water consumers generally, the water supply is to be discontinued until payment is made.

" '3. Where larger private special fire service connections (above six inches) are desired, the rates and conditions applicable thereto shall be determined by the water company, having due reference to the size of street mains, locality and surroundings, the cost necessary to the company in the premises, and the current expense of maintenance.

" '4. Such property owners now having such special private fire protection or automatic sprinkler service connections, and have paid the water company the first or original cost of installation, the same to be refunded by the company.' "

Here is a resolution of the Cleveland, Ohio, Board of Public Service, passed July 28, 1905:

" '*Whereas*, the water department is subjected to considerable expense in the inspection of fire lines, and

" '*Whereas*, the street mains have to be made larger than otherwise to keep up the pressure in adjoining buildings when a large tap for fire purposes is installed, and

" '*Whereas*, the department makes no charge for the use of water for fire purposes, therefore be it

" '*Resolved*, that beginning July 1, the following charges be made every six months for fire service, and shall be payable in advance like other water charges:

Size of Tap.	Semi-annual Charge.
$1\frac{1}{2}$-inch	\$5.00
2-inch	7.00
3-inch	10.00
4-inch	12.50
Two 4-inch	20.00
6-inch	25.00

"'No charge, however, shall be made where the fire line is metered at the expense of the owner except the semi-annual payment of $4.00 hitherto required for all meters over ¾-inch.

"'The first payments shall be made July 1, for the three months July – September 30, pro rata, and thereafter October 1 and April 1, for six months as above.

"'*Resolved*, further, that on all fire lines the owner of the property shall deposit with the water department a full drawing or plan of said fire lines satisfactory to the department within sixty days from date. Drawings of all new fire lines or changes in old ones shall likewise be deposited with the water department within sixty days after said new lines or changes have been installed. No alterations in fire lines shall be made without permission in writing in advance by the water department. Drip cocks or valves intended to drain the fire lines shall not exceed ⅜-inch inside diameter, unless with the consent in writing of the superintendent of the water department, and must be placed at the lowest point on the lines. The connection shall not be turned on or off, save by the city water department, or with the consent of the superintendent of said water department. Failure to conform to this resolution shall be followed by shutting off the water from the fire lines of the party concerned.'"

That seems to be the way these two companies, one a private company and the other a public department, make their charges for fire service. I don't know whether the people in our New England cities would stand that or not.

Mr. Charles N. Taylor.* Perhaps I might add a little information along this line. I was called upon not long ago to act as a committee of one to fix the amount to be charged a woolen mill for fire protection. I built the works two years ago, and the parties who owned the mill were large stockholders in the water works. They had not paid anything for fire protection, and the smaller stockholders naturally began to object. They had gotten a large reduction in the cost of their insurance on account of having the water, and they finally proposed, perhaps very unwisely, to leave it to me to say, as a disinterested party, how much should be paid. In order to act intelligently, I wrote to a good many different people, private and municipal companies, and finally I made the recommendation, which has since been adopted, something as follows: that they pay so much per sprinkler head

* Civil Engineer, Wellesley, Mass.

and so much per hydrant. These prices, as I remember them, are $30 per hydrant per year, and 25 cents per sprinkler head per year up to 1 000 sprinkler heads. Beyond that the price is reduced, as I remember it, to 15 cents, and the whole amount is computed on that basis. This seemed to be satisfactory after they thought it over and figured it up, and I believe it was acknowledged that, though they thought the price was high, they were saving considerably more than that in what it cost them for insurance.

In another place I have been obliged to deal with pulp mills of the International Pulp Company. The mains at Orono pass the mills, and we were several months deciding on what would be a fair price. They conceded that they wanted the water, they needed it, and we had no doubt that we wanted to sell it to them. I finally said for the company that they could have the water for $150 a year for their pulp plant, but this they said was more than they could afford to pay. As time went on, however, I presume the insurance people assisted me somewhat in getting them to come to my terms, for they finally said, All right. Another pulp mill in the same town pays us $350 a year for water for fire protection. For other purposes they pay the regular rates.

In the town of Strong, Me., is located a little toothpick mill, which, by the way, is the largest toothpick mill in the country, and that isn't saying very much, and they pay $300 a year for water for fire protection and for use for their boiler. These instances are all I have in mind, but they are actual amounts which are paid in different places and may be of some assistance.

MR. R. C. P. COGGESHALL. I should like to see Mr. French's meter tried somewhere on one of these large supplies, for I have an impression that if it works as it bids fair to work, the revenue from the aggregate of the small leaks inside of one of these large enclosures where they have pipes by the mile, would, in the course of the year, be a considerable amount, and perhaps we wouldn't need to get paid for any more than what the meter registers.

MR. GEORGE H. SNELL.* I haven't heard the entire discussion, Mr. President, but I have been interested in this subject for a number of years, and I think it is one which should be fully

* Superintendent of Water Works, Attleboro, Mass.

discussed before we decide to make a charge. The gentleman who was speaking as I came in made a remark about how many fires were put out which we didn't know anything about until afterwards. If it is a private water company, of course they are saving money, or if the works are owned by the town or city they are saving money, by having those fires put out with a few gallons of water, whereas if they hadn't been thus put out, it might have taken several million gallons of water. It is very hard to draw the line as to what we should do in the matter. If a town can afford fire protection to the people, wouldn't they be better off to furnish it and take the chances, and let them have the benefit of the low rate of insurance, rather than to charge them and run the risk that they will go to some other town where protection would be furnished for nothing? That is another thing to be considered.

I should say that if there was some way so that we could be sure that the water was not being wasted or misused in these buildings, if we could get to the point where we were sure the water wasn't being used for any other purpose than for fire, and the leaks were taken care of, I believe that would be the best solution of the question. The only fault I find on my works is with their opening the hydrants. They do it because they have a Stilson wrench, and they want to wet down ashes or something, and they use the water because they get in the habit of it. They don't do it by orders from the firm or the owners. If the hydrants are sealed, as I believe Mr. Coggeshall has all of his in New Bedford, and then we have some penalty for breaking the seal, I think that would remedy a part of the trouble, and thereby eliminate the misuse of water in this way.

MR. FRANK L. FULLER.* In our town we charge $10 for each private hydrant. There are not many of them, but those who have to pay the bills haven't made much opposition. It has always seemed to me that it wasn't more than fair or right to make some such charge. Our system has cost a good deal of money, largely because it has been built sufficiently large to provide this very fire protection which these people demand, and, therefore, it has always seemed to me no more than fair

*Civil Engineer, Boston, and member of Water Board, Wellesley, Mass.

that there should be some reasonable charge for private hydrants.

Mr. Snell. There is just one point more that I should like to mention. About two years ago we decided that we would lay all underground pipe, and set all private fire hydrants at the expense of the owners, so as to have it uniform with our own system, and in order to protect ourselves from leaks. I think that is something which every water department should look into carefully, for the work done by contract is sometimes not acceptable to the town, and it costs the town nearly as much to inspect the work as to do it themselves in some cases,—so we have found, at least. We do all the outside work which is done for private fire protection, and we find this to be a great benefit to the department.

(Mr. Chase's motion was put and adopted.)

ELECTROLYSIS.

TOPICAL DISCUSSION.

[*December 13, 1905.*]

MR. EDWIN C. BROOKS.* I have been requested to open the discussion on the subject of "Electrolysis," as we have had considerable trouble in Cambridge from electrolytic action. Two years ago our 40-inch steel main was very badly affected; we dug up about 800 feet in length of it and made some extensive repairs. We have since had several leaks in the immediate vicinity of the car barns on Boylston Street, close to the power house. Notwithstanding that the 6-inch pipe that you see before you (Plate I, Figs. 1 and 2) was alongside of the Metropolitan 48-inch pipe, you can see the destructive action which has gone on there. And I should like to call the attention of the members to this fact, that that pipe has been in the shop for just about a year, and when it was taken out of the ground and wiped off, only those places that are eaten out showed on the surface. The other part of the pipe looked like any ordinary pipe. But as it dried out, and as the rusting took place between the graphite — if that is a proper term to use — and the iron, it forced off the pieces that are formed in those cavities, and you will notice, if you examine it, that that action is going on all over it at the present time.

I have here a sample that came off from the pipe, and it shows very plainly the action which takes place, viz., that a little rust begins to form upon the clear iron at the bottom of the graphite, and as it forms it forces this piece out, and, as I say, I think you will see that action going on there in the pipe.

I was very much struck, on seeing photographs of some water pipes in Dayton, Ohio, and, I think, in Providence, R. I., by the apparently immense holes in the pipe, and I could not conceive how it was possible that those holes could have been so large when the pipe was taken up. You will see, however, that the destructive action goes on until there is a mere shell of iron between the inside of the pipe and the bottom of this substance

* Superintendent of Water Works, Cambridge, Mass.

Fig. 1. Electrolysis of 6-inch Water Pipe in Cambridge, December 13, 1904.

Fig. 2. Same Pipe as in Fig. 1, after Exposure to the Air for a Year.

that the electricity forms, and that when the pipe gives out it gives out over a considerable area, making quite a large hole.

You will see near one end of this pipe which is before you two holes, and they were the cause of our taking it out. Those two holes came at one time, and it took a plug an inch or more in diameter to plug each one of them. I think that very satisfactorily explains the appearance of these pipes that have been taken out in various places, and which look so badly.

Now, as I say, that pipe was close to the Metropolitan 48-inch main. It was crossed by a lot of car tracks going into the stables of the Elevated Road on Boylston Street. You can see that, notwithstanding its close proximity to that 48-inch pipe, it still was carrying quite an amount of current.

We have considerable trouble with supply pipes in certain sections; and we have had pipes give out under the telephone conduits as well as under the railroad conduits. It does not seem that we are immune from trouble even from the telephone conduits.

I have here some photographs * showing the condition of our 40-inch steel main as it was found two years ago, and also the method of repairing it. During the past year we have had no trouble from our 40-inch main. It has been connected with the rails at one point, and we have put in insulating joints at other places where the current was liable to go on to the pipe. We use the joint that the Metropolitan engineers have devised, that is, a flanged joint with a thick rubber gasket between, and rubber insulation on the bolts by which the flanges are bolted together, and also under the heads and nuts of the bolts.

I have been merely called upon to start the ball rolling here, and I would like to have you gentlemen who are interested in the subject look that pipe over and see if you don't think that it would be very easy, on a casual inspection of the pipe in the trench, to decide that there was no electrolytic action at all; whereas, if you took the care to examine it carefully with a pick or sharp point of any kind, you would find plenty of soft places that you could dig out. I hope, Mr. President, that you will call upon our friend, Mr. Foss, to give us a little talk on this subject, for he has looked into the theoretical part of it, and is very well

* Not reproduced. — Ed.

acquainted with the trouble we have had and also with the trouble that has been experienced generally in Boston and vicinity.

The President. We should all like to hear from Mr. Foss.

Mr. Wm. E. Foss.* Mr. President and gentlemen, these specimens that Mr. Brooks has thoughtfully brought here for our inspection direct our attention to the difficulty of detecting injury to cast-iron pipes from electrolysis, by a visual inspection only. It is usually easy to see the effects of electrolysis on a lead, steel, or wrought-iron pipe from a rather careless examination, but the injury is found on the cast-iron pipes only by a very careful examination with a testing hammer or a knife. If the pipe is of lead, steel, or wrought iron, the metal is usually completely eaten away, leaving a visible pit or hole, but if of cast iron, the iron is removed without destroying the form of the pipe which remains perfect, although the remaining substance is a soft material, like carbon, which can be easily cut with a knife or chipped with a testing hammer.

A while ago, I had occasion to examine a 48-inch pipe line for electrolytic injury, and was unexpectedly detained at the office until after the workmen had completed the excavation. As I did not appear at the appointed time, the foreman examined the pipe, and telephoned to me, reporting that he had looked the pipe over very carefully and found it as good as new, with no evidence of any injury. He was directed to keep the excavation open, and when a careful inspection of the pipe was made with a testing hammer, a large number of deep pits were found in it.

An interesting feature in connection with electrolysis is that no way has yet been discovered to entirely prevent the action where the single trolley electric railway is in operation, although investigations of the process have been made during the past ten or fifteen years.

Fairly good results have been obtained by bonding telephone cable sheaths to the rails or return wires, to protect them. A complete knowledge of the electrical conditions existing at the time the bonds are connected is necessary in order to properly locate them, and continual inspections are necessary after they are connected, to detect the continually occurring changes in electrical

* Division Engineer, Metropolitan Water Works, Boston, Mass.

6-INCH HYDRANT PIPE UNDER TELEPHONE CABLE, DESTROYED BY ELECTROLYSIS, CHELSEA, MASS.

conditions as soon as they take place, so that the necessary relocation of the bonds may be made. An objection to this method of protection is that it causes increased action on the other structures buried near the cables. An example of the damages caused in this way is given in the photograph, Plate II, which shows a 6-inch hydrant pipe which burst while the hydrant was in use during the fire which destroyed the Academy of Music in Chelsea, on January 11, 1905. This break was due to the disintegration of the iron by electrolysis at the point where it crossed under a telephone cable which had been bonded to the railway return for protection.

After bonding, the cable is actually a portion of the street railway return system, and, on account of being buried several feet below the surface in the damp ground near other structures, is more likely to cause electrolysis than a rail located on the surface. As much as 500 to 700 amperes is drained from the cables over some of the bonds.

Attempts have been made in a few places to protect the water and gas pipes from electrolysis by bonding them to the rails, but the results have not been entirely satisfactory. In two cities where the pipes were bonded to the rails about ten years ago, the pipes have remained positive to the rails in some districts, the injury to service pipes has continued, and it has recently been necessary to employ experts to investigate the electrical conditions in both places. In one of the cities, some of the bonds were located in the negative districts and delivered electricity to the pipes instead of draining off that already in the pipes as intended. The result of making the pipe system a part of the electric railway return system has been to cause enormous currents to flow over some of the pipes. It has been reported that over 3 000 amperes is flowing on a 12-inch gas pipe in one of the cities, and that the pipe is perceptibly warmed by the current.

It is a much more difficult problem to protect a pipe system than it is to protect a telephone system by bonding, on account of its interwoven network of mains and services, large extent, large surface contact with the earth, and uncertain joint resistances. To attempt to protect all of the underground structures by bonding would necessitate the bonding of all of the structures, and of the

adjacent parts of each structure together at many points and the draining of the entire structure to the railway return through a booster. That is, to completely protect the structures by this method, each structure must be made negative to every other structure, which is evidently impossible. The nearest we could approach to this condition is to maintain all the structures at the same potential, and this is practically impossible.

Experiments to determine the effect of insulation joints are now being conducted on some systems. The construction of two different types of these joints is shown by Figs. 1 and 2. The joints have a resistance of several hundred thousand ohms when tested dry on blocking in the air. The resistance falls to 100 to 200 ohms when the pipe is filled with water, and falls still lower to only a few ohms when laid in the pipe-line in the ground. What we term the resistance of the joint is, then, the resistance of the shunt around the joint through the ground. The effect of setting the joint at, say, some point near the middle of a pipe-line is to stop the direct flow of electricity on the pipe at that point, and to produce a difference of potential across the joint of some 5 or 10 volts, depending on circumstances. The potential of the section of the pipe-line on the positive side of the joint is raised, and of the section on the negative side is lowered, as a result of the operation. The electrical conditions on the two sections into which the pipe-line is divided by the joint become similar to those of the original line, each section having a positive and negative portion. The efficiency of the joint for decreasing electrolysis depends on many local conditions, such as the number used and character of the ground where they are placed, etc. The result of setting some 6 or 8 on one system consisting of two lines of 48-inch pipe, each about 8 miles long, has been to reduce the total current leaving the pipes by about 30 to 50 per cent.

The insulation joint method, like the bonding method, is liable to produce conditions which will cause increased action on adjacent structures, but there is the distinct difference between the two methods, that the bonds increase the currents on the underground system to a maximum, while the insulation joint reduces the currents to a minimum.

In England, the government authorities have prevented

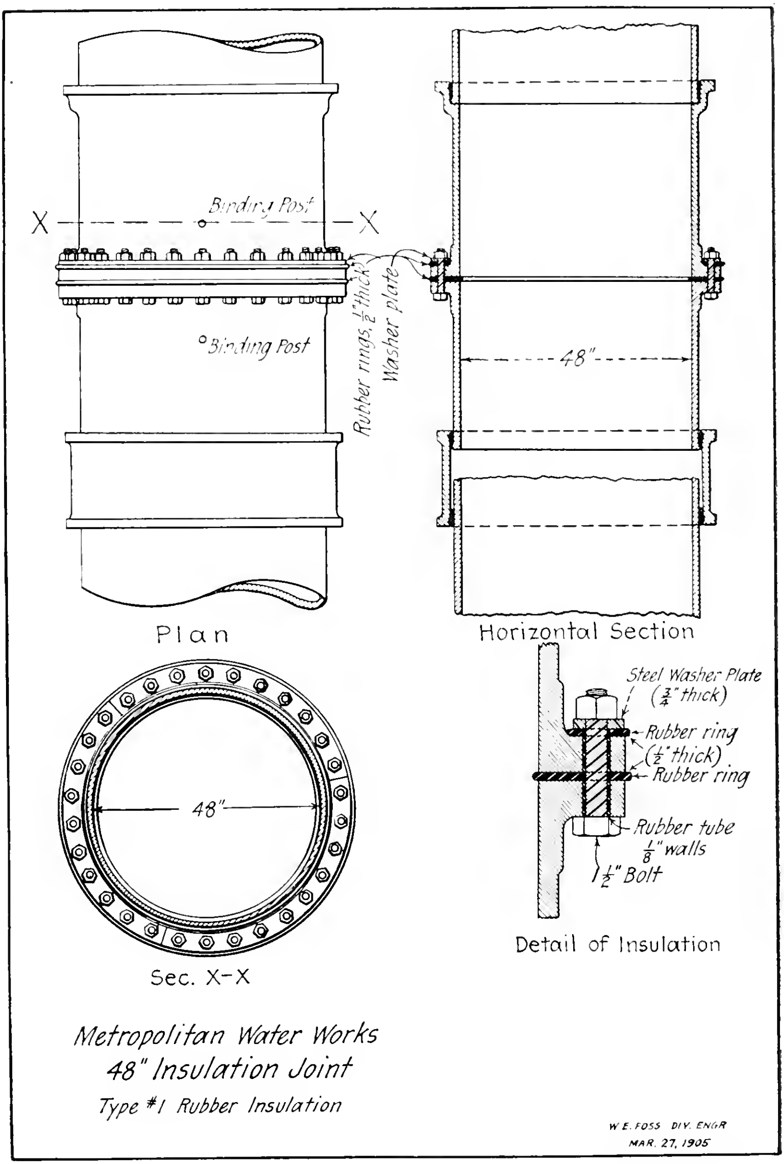

Binding Post
X
X
Binding Post
Rubber rings, ½" thick
Washer plate
48"
Plan
Horizontal Section
48"
Sec. X-X
Steel Washer Plate (¾" thick)
Rubber ring (½" thick)
Rubber ring
Rubber tube ⅛" walls
1½" Bolt
Detail of Insulation
Metropolitan Water Works
48" Insulation Joint
Type #1 Rubber Insulation
W. E. FOSS DIV. ENGR
MAR. 27, 1905

FIG. 1.

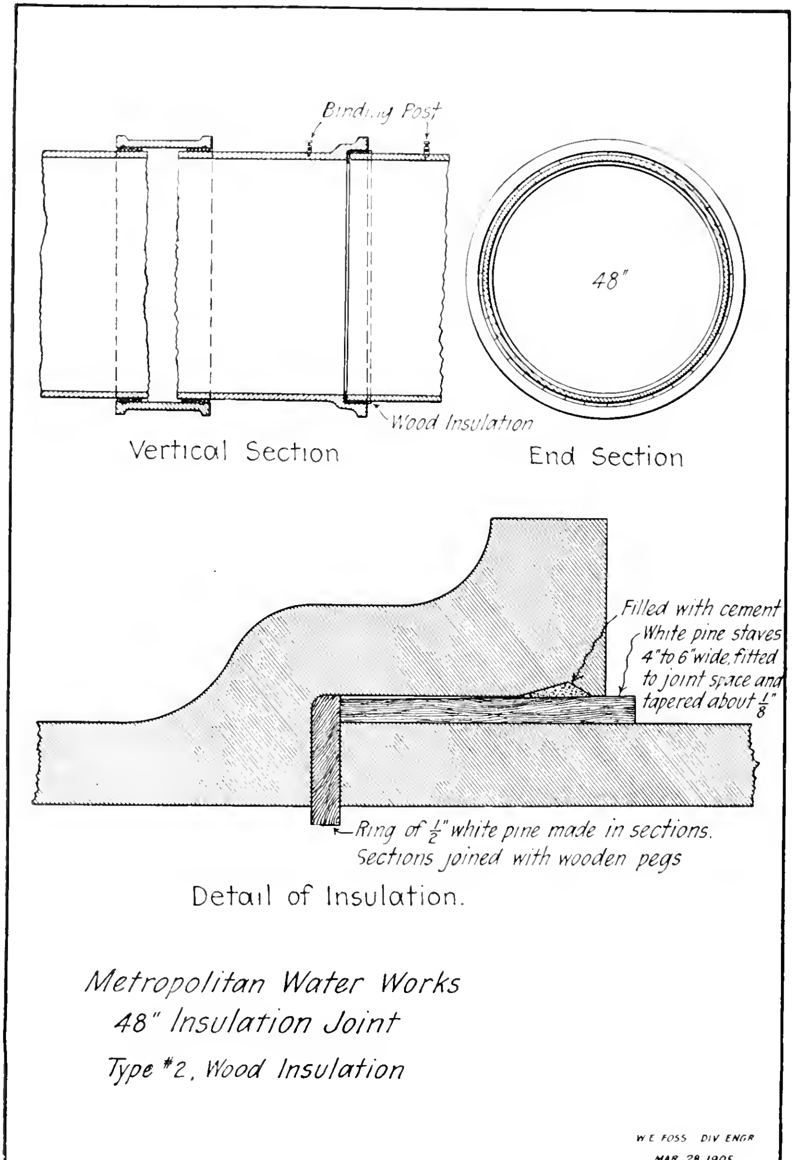

Binding Post
48"
Wood Insulation
Vertical Section
End Section
Filled with cement
White pine staves 4" to 6" wide, fitted to joint space and tapered about 1/8"
Ring of 1/2" white pine made in sections. Sections joined with wooden pegs
Detail of Insulation.
Metropolitan Water Works
48" Insulation Joint
Type #2, Wood Insulation
W E FOSS DIV ENGR
MAR 28 1905

FIG. 2.

electrolysis in a large measure by regulations which provide that the maximum difference of potential between any two points on a single-trolley electric railway return system must not exceed 7 volts, and that the railway company shall keep records of the maximum difference of potential and report to the authorities at stated intervals. The results from these regulations are reported to be very satisfactory, and undoubtedly they have prevented a large amount of damage. As the amount of electrolysis in any given district varies directly with the potential differences maintained on the railway return system, the reduction of these differences to a minimum should be the first step to take to reduce the damage which is being done. If the English regulations were applied to the railway systems in the United States, the amount of damage done by electrolysis would be reduced by 60 to 90 per cent.

The protection of pipe-lines from electrolysis by means of insulating coatings has been tried experimentally. All of the coatings applied to pipes after they had been laid in the ground have failed to protect the pipes. Asphalt, tar and burlap, electric tapes and cement have been used as coatings. Several other insulating coatings applied to short pieces of pipe have shown high insulation values in laboratory tests, but we have not yet obtained any reliable data regarding their practical value.

THE PRESIDENT. We should like to hear from Mr. Gould on the gas companies' experience.

MR. JOHN A. GOULD.* I do not know that I have anything new to say on this subject. The gas pipes never were so badly affected as water pipes, although we have had some trouble, but I think less at the present time than we used to have. We had to take out one cast-iron main, which had been laid five or six years; but that was some seven or eight years ago, and I think that is the last one destroyed by electrolysis. We have had service pipes destroyed in eighteen months. I think the troubles in Boston are decreasing. We never have had so much trouble here as they have had in Cambridge, and less trouble with gas pipes than with water pipes. I suppose one reason is that we make a good many cement joints, which make a poorer conductor than lead, and then the water itself in the water pipes is a good conductor, while gas

* Engineer Boston Consolidated Gas Company.

has no conductivity. I know of one case of a gas main which has been laid with insulating joints, parallel with a trolley line where they were liable to be troubled by the return current, and up to the present time there has been no trouble that I have heard of. This line has a rubber gasket at every joint. It is a high-pressure line requiring special care, because if it gave out, the gas, being under 10-pound pressure, would create considerable disturbance. I suppose that there will really be no final solution of this problem until the trolley lines use the alternating current, and then our troubles in this direction will cease.

MR. T. C. GLEASON.* About six weeks ago I took out some wrought-iron pipe, and although I had never had any trouble with electrolysis so far as I knew, the pipe looked so peculiar that I brought a specimen of it down here to-day thinking that there would be some gentleman present who could inform me whether this shows electrolytic action or not. I should like to have you look at it and see what you think about it. (The specimen is passed around for examination.)

MR. R. C. P. COGGESHALL.† Mr. President, in our city we have not yet, so far as we know, had any serious trouble with electrolysis. Our steel force main, however, which leads from our pumping station 11 miles outside of the city, is crossed about two miles below the pumping station by the street railway line that runs from Middleboro to New Bedford. A short distance below the pumping station a 2-inch service pipe taps into this force main and leads out into the road crossing beneath the tracks of the trolley line where there is a brook, and then continues to the engineer's house. At the brook, we have had four lines of pipe completely destroyed, and Mr. A. A. Knudson, a member of this association, has been called upon two or three times to investigate the trouble. The current apparently passes upon the pipe at the place where the track crosses the large main two miles below the pumping station, and returns upon the force main and the 2-inch service pipe to the brook crossing, where it leaves the pipe and returns to the rails.

About a year ago a young man named Cecil T. Wilkinson, who is connected with the General Electric Works at Schenectady,

* Superintendent of Water Works, Ware, Mass.
† Superintendent of Water Works, New Bedford, Mass.

passed his vacation with us, and the subject of electrolysis coming up, he was at once interested. He said he had made it the subject of a good deal of study in England, and he was very much interested in Mr. Brooks's Cambridge report, a copy of which I obtained for him. Last summer he passed his vacation with us, and of his own volition took the instruments and went out and made an examination. One little suggestion he made may be of interest. I don't know how much value there is in it, but he told me the same thing that Mr. Foss has told us, that they had taken care of this trouble a good deal better in England than they appeared to have done in this country. Speaking of this pipe he says:

"Another alternative, perhaps less expensive, which I have carefully discussed with our railroad engineers" — that is, the engineers at the General Electric Company — "would be to put the 2-inch service pipe now installed in a wooden trough containing unslacked lime, this trough to run about 50 feet south of the point where the rails pass over the pipe and about 150 feet north of that point, or 200 feet in all."

Then in a later letter he says:

"With regard to the discussion of this subject at the meeting of the New England Water Works Association, if the opportunity occurs for you to mention the use of lime, I would be very glad to have you do so.

"When tar, or paint, or cement of like nature is used as a coating for water pipes to protect them against the electrolytic action, there almost invariably occurs the formation of pockets in which the saline matter of the soil collects, causing very vigorous action at certain points. The complete success we have had on a small scale and under suitable conditions with unslacked lime is not remarkable when you consider that it is theoretically the absolutely correct thing to use. Electrolytic action is due only and entirely to the sulphides, chlorides and nitrates dissolved in the soil, and when the water from a rainstorm percolates through the earth, it carries down on to the surface of the iron pipe all these acid salts in solution. If, therefore, before reaching the pipe it passes through a layer of a few inches of lime, all these salts are neutralized and no action whatever occurs. We have even found the

surface of the pipe entirely free from all traces of pitting when other metal unprotected in this way has been completely pierced with holes. If any member of your association wishes to try this scheme I shall be very glad to hear how he succeeds.

"To be perfectly frank, I do not at the present know definitely why it is better to use the lime unslacked when first put on to the pipe, but undoubtedly better results are achieved in that way."

THE PRESIDENT. I am told, Mr. French, that you have had some trouble with electrolysis.

MR. A. N. FRENCH.* I don't think I can add anything to what has already been said, Mr. President. We have had some little trouble on our service pipes, but nothing very serious on our mains, and we are learning something every day. We have had one case of electrolysis under a steam railroad which seemed a little peculiar.

MR. HORACE G. HOLDEN.† I should like to inquire, Mr. President, whether any water departments or water companies have ever received any payment of damages from the trolley companies on account of electrolysis. It seems hard if the water company has to stand all the loss.

MR. COGGESHALL. I will say that in our case the Old Colony Railway Company, which has been the source of our trouble, has been paying the bills for repairs.

An interesting point that has come up in our town has been in connection with the electric road itself. Its power plant is located on the water front and it draws the condensing water from the river and delivers it into the river, and one of the pumps has been completely destroyed by the return current which came from the river into the hot-air pump.

THE PRESIDENT. The electric roads themselves have started to look out for their rails by going over their entire track with a car provided with apparatus which will give them a definite spot where the current leaves the rails; and when that is done, if they will take care of it and remedy the trouble at those points, we are going to get rid of a good deal of our difficulty. I tried to get a representative of the railroad company to come here to-day and

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* Superintendent of Water Works, Hyde Park, Mass.
† Superintendent of Water Works, Nashua, N. H.

explain the apparatus, but he was not able to come. At some future time if we can have him here I think it would be very interesting. Would any one else like to speak on this subject?

MR. BROOKS. I may say, Mr. President, that I have found that the railroad company is very cautious about recognizing the word "electrolysis." It is willing to pay in some cases for repairs but it doesn't want "electrolysis" or "electrolytic action" spoken of in the bill. We can call it by any other name we like, but we steer clear of that.

MR. J. C. HAMMOND, JR.* We have had three of our lead services completely honeycombed, and we don't know what else to lay it to except electrolysis. I would like to ask if any one has had any such experience as that.

MR. BROOKS. I will say, in answer to Mr. Hammond, that when the West End power station was first established at East Cambridge the city tried using lead services down there and found them of no use at all. They went more rapidly even than the iron pipe, and so the idea of protecting the services by having them of lead was abandoned.

MR. EDWARD V. FRENCH.† Mr. President, isn't it a fact that whenever a current gets on to a pipe, even if you provide a proper means for it to get on and a proper means for it to get off, there is likely to be a good deal of trouble at each joint, or at least at the joints which happen to be rather poor conductors, because of the way the lead or oakum happens to be put in?

It seems to me that this is an exceedingly important question, involving, if the trouble goes on, the expenditure of a great deal of money in some places to repair the damage which is probably being done, especially if the trouble is going on in this somewhat hidden way only to show itself unexpectedly some day. I was wondering whether the study of the subject has gone far enough so that it would be possible for the association or a committee to make some definite suggestions for the detection and the remedy of the danger. Perhaps in the large cities the railway companies are watching conditions very carefully, and I do not know exactly what the present condition of the whole work is, but it occurs to me

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* Treasurer, Water Company, Rockville, Conn.

† Inspector, Associated Factory Mutual Insurance Companies, Boston.

that it is a matter of so much importance that if the association could suggest some standard means of finding the trouble and some method of remedy, it would be a distinct gain in the long run. It may be that things are not in condition so that this can be done, but the idea occurred to me and I thought it was worth expressing.

MR. GEORGE E. WINSLOW. Mr. President, there has been a good deal said here at times against a certain kind of pipe that has caused a good deal of trouble in other ways than from electrolysis, namely, the old cement-lined pipe. Hiram Nevons, while superintendent at Cambridge, at one time said that a cement pipe could be made which would be the best pipe in the world by taking the ordinary cast-iron pipe that is used at the present time and lining it with cement and covering it with cement. I think so, too. And, furthermore, — I am talking on a subject that I am not very familiar with, and perhaps I may say something which is wrong, but you will take it for what it is worth. — there is a good deal of resistance in cement to the flow of electricity, how much I don't know. I do not know, however, of any place where cement pipe is in use where electrolysis has affected the mains. I know also that when lightning strikes a cement pipe and breaks it, which it sometimes does, the break is generally in the joint where the end of the pipe is exposed to the water. The question has been in my mind ever since this discussion began here to-day as to the feasibility of insulating the mains by cement and thereby perhaps getting something by which we will obviate the danger of electrolysis, or will stop the rusting of the pipes and other things of like nature, as a cement pipe never fills up. I want to assure you that I am not in favor of cement-lined pipe as ordinarily made of thin sheet iron covered inside and outside with cement, and I certainly should want something a little stronger than that. I merely speak of this as a suggestion in the way of insulation.

MR. FOSS. I think that Mr. French's experience in Hyde Park will be of some interest. Mr. French had trouble with his service pipes, and he finally boxed one of them in a wooden box and filled it up with cement, and a year or so afterwards he had to go and relay the pipe, so that the cement as put in at that time certainly did not stop the action. Regarding the point brought out by Mr. Edward V. French, I think that with the improve-

ments made during the past few years in methods of investigating electrolytic troubles, there is no reason why we cannot locate any action that is going on. We can now measure the current flowing on the pipe and follow it down to where it is leaving the pipe, and, in general, locate the bulk of the damage. We cannot locate every point where damage is being done, but we can obtain a very good idea of the total damage, and the location of it.

MR. FOSS (*by letter*). Mr. Gould has suggested that troubles from electrolysis would cease when the street railways adopted the alternating current instead of the direct current. This is, perhaps, a natural conclusion from the alternations of polarity, but does not seem to be a fact, for, as shown by the following quotations, alternating currents apparently cause nearly as much electrolytic action as do direct currents.

Dr. Guglielmo Mengarini says, in *The Electrician* (London), Vol. 27, p. 336, July 24, 1891:

In a voltmeter containing acidulated water, or a saline solution, the quantity of the electrolyte decomposed at an electrode by an alternating current (the current density at the electrode and the number of alternations remaining constant) increases if an obvious recombination of the gases at the other electrode takes place. Owing to this recombination, a direct current is superimposed on the alternating current, modifying its character.

In this way, with alternating currents, metallic deposits of copper, silver, nickel, etc., quite equal to those produced by direct currents can be obtained.

. . . .

During electrolysis by alternating currents, the electrodes are vigorously attacked and quickly destroyed.

Even platinum, gold, and iridium become covered with a powder which increases until it finally completely destroys the electrode.

Abstract from "Alternating Current Electrolysis," by Prof. Ernest Wilson, in *The Electrician* (London), Vol. 48, p. 1025, April 18, 1902:

Experiment with pure lead. Electrodes of the same size as for previous experiment were cut from a sheet of pure lead, and two electrolytic cells were prepared with dilute sulphuric acid as electrolyte. In each case the current had about the same density

of 0.024 amperes per square centimeter of active surface, but the frequencies were 92.5 and 21.5 respectively. . . . The plates were weighed before and after the experiment. It will be seen from the table that the total diminution in weight, which was equally distributed between the two plates in a given cell, is nearly twice as great at low frequency as it is at high frequency. A test made by Mr. Skelton, in the Chemical Department at King's College, London, shows that the deposit at the bottom of each cell is lead sulphate. . . . In this experiment, the ratio of the maximum coulombs at 92.5 and 21.5 periods per second is 0.23, . . . and the ratio of the diminution in weight 0.54. The average watts during the experiment are nearly the same in each case. These results indicate that frequency plays an important part in the reaction.* Pieces of the same sheet of lead immersed in a portion of the same electrolyte are only slightly discolored in the same time, so that it is the electric current which produces the effect.

Average frequency in periods per second during experiment	92.5	21.5
Total weight of the two plates in grams before experiment	801.167	798.084
Total weight of the two plates in grams after experiment	784.667	767.884
Total loss in weight in grams	16.5	30.2
Area of active surface of each plate in square centimeters,	160	160
Time current was passing through each cell in hours	15	15
Distance between plates in centimeters	0.317	0.317
Average of amperes during experiment	3.74	3.80
Average of amperes per square centimeter of active surface	0.0236	0.0236

(From Minutes of Proceedings of the Institution of Civil Engineers, Vol. 149, 1902.)

Philip Dawson (p. 96) said: His experience, with the fairly low frequencies which must be adopted for traction with alternating currents, was that the electrolytic action was nearly as bad as with continuous currents; the difference was that with continuous currents the resulting damage was limited to an area which could be predetermined, and safeguarded by means of additional return cables or negative boosters; whereas with alternating currents the area was not limited, and the damage was likely to be caused over the whole system.

W. H. Massey (p. 100) said: With regard to alternating currents and electrolysis, experiments he had conducted about four years ago had left no doubt whatever that, provided the frequency was low enough and the current sufficiently large.

* In alternating current railway work, a frequency of about 25 cycles is employed at the present time. — Ed.

electrolytic action occurred just as badly, or was even worse, with alternating currents than with continuous currents.

W. H. Molesworth (p. 101) said: The electrolytic action of alternating currents of low frequency, as advocated for railways, was as serious as that due to continuous currents.

W. M. Mordey (p. 161) said: It had been stated that alternating-current electrolysis was worse than continuous current; as a matter of fact it did not seem to be as bad, at least, with such low-current densities as were likely to be met with in railway practice. It only began with a current density that would give enormous deposition with continuous currents. In the experiments of G. Mengarini on the electrolysis of liquids,* it had been shown that until a density of four amperes per square inch was obtained there was no electrolysis at all. With continuous currents there would be large volumes of gas coming off with such a current density as that.

(From Minutes of Proceedings of Institution of Civil Engineers, Vol. 151, 1903.)

A. P. Trotter (pp. 96, 97), in discussion on Electric Tramways, said: He had felt that it was not likely alternating currents would be free from corrosion; and, taking two pieces of lead pipe, one of which was on the table, he had buried them in moist earth in a box, and had subjected them for a month to an alternating current, from Deptford, of one ampere. The two pipes had faced each other, about 4 inches apart. A thick white crust of what he thought was carbonate of lead had formed. It was an interesting fact that the patch was definitely limited, showing that at less than a certain current density, or difference of potential, no corrosion took place. He had used lead because, the electrochemical equivalent of lead being higher, the product of the action was of larger amount than with iron; and further, it was an insoluble white crust which could easily be seen. Recently Mr. Mordey, in reply to the discussion upon his paper, had suggested† that the experiments made by G. Mengarini showed that alternating currents at a less density than four amperes per square inch would not cause corrosion by electrolytic action. He had measured the area of the pipe affected, and had found it to be about 40 square inches; so that about 1-40 ampere per square inch had produced the effect shown. After Mr. Mordey's remarks,

* *The Electrician*, Vol. 27, pp. 304 and 334. It appears, however, from this paper that, at higher densities than that given above, the action on the electrodes may be more destructive than with continuous currents; *e. g.*, even platinum electrodes may be acted on and destroyed. See also, R. Malagoli: L'Éclairage Électrique, Vol. 13, p. 255.

† Minutes of Proceedings of Inst. Civil Engineers, Vol. 149, p 162.

he had thought it would be well to make some experiments to ascertain whether there was a critical current density below which no corrosion might be found. He had already tried many experiments on lead wire in the Board of Trade Laboratory with continuous current, in attempting to find such a point; but he had not found it. In his experiments he had not used clay or gravel, but simply ordinary damp soil. Chemists, he believed, gave the name "humus" to the active principle of soil which was supposed to attack the lead. He had started the experiment with alternating current at 83 periods per second, and with the current density at which he had left off in the previous experiment, namely, 1-40 ampere per square inch. Taking four lead plates, each 4 inches square, he had painted them with varnish, with the exception of square spaces in the middle, as shown by the following table:

	Unvarnished Portions of Surfaces.		Current-Density.	
Plate No.	Front.	Back.	Ampere per Square Inch.	Amperes per Sq. Meter.
1	$\frac{1}{2}$ inch x $\frac{1}{2}$ inch	1 inch x 1 inch	front 1-40 back 1-160	38.7 9.7
2	2 inches x 2 inches	2 inches x 2 inches	1-640	2.42
3	3 ,, x 3 ,,	4 ,, x 3 ,,	1-1440	1.075
4	4 ,, x 4 ,,	4 ,, x 4 ,,	1-2560	0.605

By the end of a month a thick white incrustation of lead had formed on Nos. 1 and 2, and a thinner coating on the larger plates, the corrosion being apparently proportional to the current density. (The speaker exhibited the plates.) With continuous current the corrosion would probably have been about double. Such experiments were well worthy of attention, and he hoped the National Physical Laboratory, which had much better facilities than he had, would continue them. So far as the frequency of alternating currents was concerned, he would imagine that the lower the frequency, the greater the chance of corrosion. He supposed that since the product was an insoluble salt of lead, what was produced by one phase was not decomposed by the other phase. There was no possibility of protection in alternating-current work by arranging the polarity of the conductor, as there was in continuous-current work.

ON THE PRESENT RELATIVE RESPONSIBILITY OF PUBLIC WATER SUPPLIES AND OTHER FACTORS FOR THE CAUSATION OF TYPHOID FEVER.

BY W. T. SEDGWICK AND C.-E. A. WINSLOW, PROFESSORS IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[*Read November 9, 1905.*]

In a paper read before this Association in 1901, the rise and progress of water-supply sanitation in the nineteenth century was traced with some care. (Sedgwick, 1901.) It was then shown that the responsibility of public water supplies as sources of typhoid fever was first made conspicuous by the epidemics at Lausen, Switzerland, in 1872 (Hägler, 1873), and at Caterham, England, in 1879 (Thorne Thorne, 1880). In this country evidence of the same character was not long lacking; for in 1885 the thriving mining town of Plymouth, Pa., suffered one of the most disastrous water epidemics of which we have even yet any record. (Taylor, 1886.) The great epidemics at Lowell and Lawrence in 1890–91 added new emphasis to the previous lessons (Sedgwick, 1893, *a*); but nevertheless a majority of the largest cities of the United States have continued almost up to the present day to drink water more or less infected with typhoid fever. In the period 1898–1903, there were nineteen cities in the United States of over 200 000 population. Twelve of the nineteen were furnished with public water supplies drawn unpurified from polluted rivers or lakes. The typhoid death-rates in these cities per 100 000 population were as follows (Fuller, Ferguson, and Jeup, 1904):

Pittsburg	122
Washington	66
Louisville	60
Cleveland	51
Philadelphia	51
Cincinnati	45
Minneapolis	42

Chicago	31
St. Louis	31
Buffalo	29
Detroit	18
Milwaukee	18

For the other seven cities not having supplies drawn from grossly polluted sources, the corresponding rates were as follows:

New Orleans	49
Baltimore	35
San Francisco	31
Boston	26
Jersey City	22
Newark	21
New York	19

There are causes other than the public water supply for the high typhoid death-rates in New Orleans and perhaps in Baltimore. Where no such factors are operative the cities with reasonably pure water supplies exhibit typhoid rates ranging from 20 to 30; 25 would be a fair average figure for American cities of this class. The excess over 25 deaths per 100 000 in the case of Pittsburg, Washington, Louisville, Philadelphia, Cincinnati, and Minneapolis is unquestionably the tax paid by those municipalities for their polluted water supplies. In the first five cities alone this needless waste amounts to 1 200 lives per annum.

And yet great progress has been made in the right direction. The replacement of water derived directly from polluted streams, by filtered or well-stored supplies, goes on with increasing rapidity. Jersey City, for example, where the typhoid death-rate ranged from 52 to 94 between 1890 and 1896, in the latter year abandoned the Passaic River at a point where it was heavily polluted by the sewage of Paterson and Passaic, with the result that the rates for the four years immediately succeeding fell to 21, 36, 15, and 21. Albany effected an equally striking reduction in its typhoid death-rate when a municipal filter was introduced in 1899. (Fuller, Ferguson, and Jeup, 1904.) Of the other communities mentioned above, Washington and Louisville have installed filtration plants within the present year. Philadelphia's system is partially installed, and one of the most serious indictments against the one-time bosses of that apparently redeemed city is

the charge that the delay in the completion of this sanitary work is responsible for 1 200 deaths from typhoid fever. Pittsburg and Cincinnati, too, have begun the construction of municipal filter plants, and before many more years the large American city which drinks the unpurified water of a stream, or of a lake with unprotected watershed, will be an exception and an anomaly.

Of special interest in this connection are the statistics of the state of Massachusetts, where the supervision of the public water supplies has been more thoroughly carried out than in any other American commonwealth. In the period 1886–90, the typhoid death-rate for Boston was 39 per 100 000, and for Newton, with an excellent ground-water supply, was 40. The rate for all the cities of the state taken collectively was somewhat higher (46), and the two large cities of Lowell and Lawrence, using the polluted water of the Merrimac River, had each a rate of 112. As later events showed, two thirds of the typhoid fever in Lowell and Lawrence was caused by water, and this excess, of course, materially raised the rate for the total urban population of the state.

Between 1891 and 1895 the unpurified river-water supplies of Lowell and Lawrence were abandoned, and for the period 1896–1900 their rates fell to 25 and 24 respectively. In at least one of these communities, Lowell, the present water supply, from a series of driven wells, is absolutely protected from infection. In Newton with a rate of 20 and in Woburn with a rate of 13, the conditions are similar. Gloucester, Pittsfield, and North Adams, with rates of 16, 25, and 39 respectively, possess surface supplies of unexceptionable quality from uninhabited watersheds, probably as free from pollution as such waters can often be.

The North Adams typhoid rate may be regarded as due to certain exceptional conditions. We may, however, consider the other five communities as typical of most of the cities of the state, differing only in the fact that our knowledge of the purity of their water supplies is more certain than in other cases. In these five cities we find typhoid rates of 13, 16, 20, 25, and 25. We are confident that these rates are not raised by pollution of the public water supplies and that the influence of private well water upon them is negligible. It therefore follows that typhoid deaths rang-

ing from 15 to 25 per 100 000 are due in these cities to causes other than polluted water; and it is probably fair to assume that at present in similar American communities about this amount of typhoid fever may be expected to occur without its intervention. When we find that the typhoid rate for the whole of Massachusetts in 1896-1900 was only 24, in 1901 only 19, and in 1902 only 22, it seems evident that in this state at least public water supplies are not factors of paramount importance. Eternal vigilance is, of course, the only price of freedom from water-borne typhoid. Particularly in the case of unfiltered surface supplies, such as are common in New England, danger must always be recognized as possible. The 450 cases of typhoid fever at New Haven in 1901 (Smith, 1902) were caused by temporary pollution on a watershed quite as good as that of many a supply in Massachusetts. So great is the danger of such a mishap that as the country becomes more densely populated it must eventually be recognized that no surface water is safe for drinking without purification. Even with filtered supplies only careful and constant supervision will insure safety. Witness the 1 270 cases of typhoid fever at Butler, Pa., in 1903, due to almost criminal carelessness in the operation of the filter plant of the local water company. (Soper, 1903.) The responsibility which rests upon water-works officials still remains, and must always remain, heavy; but, broadly speaking, when this responsibility is well discharged, we may say with confidence, in the light of the expert knowledge at our disposal, that public water supplies play an insignificant part in the causation of typhoid fever in New England.

It must also be remembered that our requirements as to the purity of our supplies have all along been steadily rising and that a far higher degree of purity is to-day demanded, and rightly demanded, in water supplies than was formerly expected or possible. The extraordinary demonstration furnished by the experience of the city of Lawrence with filtered water, in which it has been shown by Mr. Hiram F. Mills and by Hazen (Hazen, 1905) that the general death-rate has been reduced much more than the typhoid death-rate, can only mean that the germs of other common diseases besides typhoid fever are carried by water, unless, indeed, it turns out in the future, as is possible, that the

vital resistance of the people using the water has been increased, as the purity of the water has risen. Either alternative is extremely suggestive for water-works officials, and opens out inviting fields for investigation and research.

With the progress of sanitary reform the relative responsibility of water for typhoid fever necessarily decreases. As recently as 1902, Mr. M. N. Baker wrote, "Not only is typhoid one of the leading causes of death in America, but the greater part of it is conveyed, directly or indirectly, through water." (Baker, 1902.) This is still true in Philadelphia and Pittsburg, but it is not true to-day, as we have seen, in Massachusetts. Meanwhile, year by year the relative importance of what we may call the *residual typhoid* becomes greater. It is increasingly necessary that the attention of sanitarians should be directed to that tax of 15 to 25 deaths (which means 150–250 cases) per 100 000 population, which typhoid fever still levies on communities provided with ever so pure a water supply. To what shall we attribute this residuum of the disease, so constantly present in most American cities?

In attacking this problem, which concerns not only the epidemiologist but also the practical water-works official who desires to know just how far the water supply under his care may justly come under suspicion, we must begin by remembering that the extension of an infectious disease is the spread of a microscopic parasite; and that this follows much the same course as the distribution of any higher plant. Wheat comes from the ear and eventually finds its way to a favorable soil where it may sprout. So the seed of typhoid infection originates in the body of the typhoid patient and germinates in the intestinal canal of a susceptible victim. The intermediate steps in the history of the wheat may be various. The wind, or a bird, the hairy coat of an animal, or the hand of man, may carry the grain from the place of its origin to the new soil where it sprouts and multiplies. Equally diverse may be the paths by which the typhoid germ is propagated from person to person. Air, earth, water, milk, fruit, flies, soiled clothing, human beings, may intervene; or the transfer may be so direct as to require no intermediary save the two individuals chiefly concerned.

The more we study the prevalence of typhoid fever, the more it becomes evident that its spread goes on in two ways. The first is that in which infection is distributed by a single common medium to a large number of persons at one time. This is characterized by the sickening simultaneously, or at least within a period of a fortnight, of a number of persons who have, perhaps, partaken of some common article of food. Such an explosive outbreak is what the public generally means by an epidemic. Sometimes, on the other hand, we find an undue prevalence of typhoid fever without such coincidence in time and, therefore, of exciting cause. An excessive number of cases of the disease occur which cannot be connected by any common epidemiological bond, but follow each other in a slow succession of scattered or sporadic cases, or in that closer association as to locality to which the older sanitarians applied the word "endemic." As this word is outworn, because by custom associated with the idea of some mysterious but wholly intangible quality inherent in a definite soil or region, the term *prosodemic* has been suggested by one of us for this form of disease "which progresses gradually from person to person by routes which, whether direct or indirect, are often different for each individual case," the term *epidemic* being restricted to "that special case in which circumstances permit the transfer of infection to a large number of persons through the same medium, and at approximately the same time" (Winslow, 1901).

True epidemic typhoid, in the sense in which we have thus defined the word, is generally easy to trace back to its exciting cause. The coincidence of cases fixes the date of infection with approximate accuracy, and the scope of inquiry is at once narrowed down to those vehicles of infection to which all the sufferers have been jointly exposed. Furthermore there are comparatively few methods by which typhoid infection is likely to be transmitted to a large number of persons at the same time. The vast majority of recorded epidemics have been traced with reasonable certainty to one of three vehicles, water, milk, or shellfish. Of these water is by far the most important.

The residual typhoid which still afflicts American cities and large towns, even after they have acquired good water supplies, is undoubtedly due partly to occasional epidemics in which

the vehicle is some material other than water, — such as small milk epidemics, shell-fish epidemics, celery epidemics, and the like, — even where outbreaks of notable size, in which the infection of a large number of persons can be traced to a common source, are absent. Outbreaks due to milk, although considerable, account, however, for but an insignificant proportion of the total and constant annual mortality; and epidemics distinctly traced to shell-fish and raw vegetables have been still more exceptional.

Most of the typhoid cases which occur to-day in Massachusetts and in other communities provided with reasonably good water supplies, are of the sort we have designated as "prosodemic." They are transmitted from person to person by routes which differ in individual cases. The methods by which infection spreads are almost infinite in number. The chain begins with excreta and ends usually with food; but the intermediate links may be few or many. The fingers of unprofessional attendants upon typhoid patients, or of the patients themselves during the early stages of the disease, and flies, which so often pass freely from infected privies to adjacent larders, suggest themselves as ready vehicles. Sometimes the route is so direct that typhoid fever, under uncleanly conditions, becomes for all practical purposes a contagious disease. Sometimes it is so roundabout as to baffle any attempt to trace it.

The devious and obscure course of prosodemic typhoid is no new discovery. It has never been shown more clearly than by Dr. William Budd in his famous monograph published in 1873. (Budd, 1873.) The little village of North Tawton in England suffered a severe outbreak of this character in 1839, over eighty cases occurring between June and November of that year, following each other slowly, several members of a family taking the disease in almost every house in which it appeared. Three infected persons left the place during this summer, and each one formed a new focus for the spread of fever in a region hitherto free from it. In the first case the two children of the sufferer succumbed to the infection; in the second case a friend who acted as nurse took the disease and in turn transmitted it to his two children and his brother; the third of the visitors left North Tawton to stay with a brother at another hamlet seven miles

away; the brother's wife, the brother himself, two farm hands, a friend who had come to take charge of the house, another farm hand, two servants, and the daughter of the original visitor successively developed typhoid fever. Evidence of the direct transmission of the disease could scarcely be more conclusive.

In this country the outbreak at Bondsville, Mass., where one hundred cases occurred among the mill operatives in the summer of 1892 (Sedgwick, 1893, *b*), and that of Newport, R. I., in 1900, in which some forty cases, apparently caused by an infected well, were followed by double that number of secondary cases (Winslow, 1901), furnish more recent examples of the same phenomena. In each of these instances the slow succession of cases and the bond of physical association between the victims gave evidence of the prosodemic character of the disease.

There can be little doubt that the emphasis on water and milk epidemics, which produce a striking effect upon the public mind from the number and coincidence of the resulting cases, has led to a general neglect of the less obvious but equally grave danger involved in the spread of prosodemic typhoid. Even the well-water theory may be overworked, for long ago Dr. Rolleston remarked: "And I would add that certain observations which I made recently in a fever stricken village . . . have induced me to think that of the two recognized foci for infection [in typhoid fever], the bespattered privy and the contaminated well, the former may be the one which is more commonly at work." (Rolleston, 1869.) The doctrine that typhoid fever is "infectious but not contagious" has slain its thousands. In dirty surroundings, typhoid is essentially a contagious disease. Even among trained attendants, with all the advantages of a hospital environment, the number of secondary cases of typhoid is considerable. Collie has recorded that one hundred cases occurred in the staff of the Asylum Board Hospitals of London from 1892 to 1899. (Collie, 1904.) In the unsanitary conditions which, to our national disgrace, prevailed in the camps of our volunteer soldiery during the Spanish War, the conditions favorable to the transmission of disease reached a maximum and furnished a striking object lesson in the transmission of prosodemic typhoid. (Reed, Vaughan, and Shakespeare, 1904.) Of 107 973 officers and men in the national encampments

during the year 1898, 20 738, or nearly one fifth, developed typhoid fever, with 1 580 deaths. The disease was spread in a series of independent company outbreaks affecting over 90 per cent of the volunteer regiments within eight weeks of their assembly in camp. Infected water played no important part. Flies undoubtedly served as carriers of infection, and it was believed that the virus was disseminated to some extent in the form of dust. The vast majority of the cases, however, were caused by more or less direct transfer of infected material under unsanitary conditions. Of 1 608 cases which were studied in detail, 62 per cent were definitely connected in place and time with earlier cases. The chief factor controlling the incidence of the disease was the system used for the disposal of excreta. Thus, in the Seventh Army Corps, the First Division, with a water-carriage system, had 1 039 cases of typhoid fever; the Third Division, with regulation pits for disposal, had 1 292 cases; the Second, with the thoroughly unsanitary "tub" system, had 2 693 cases. This history of typhoid in the army is simply the history, on an intensive scale, of all prosodemic typhoid.

One of the most interesting features of the "residual typhoid" (not due to polluted water supplies) is its definite seasonal prevalence. In communities provided with reasonably pure water supplies, the typhoid, or as it was called by the older sanitarians, the "fall fever," follows the curve of seasonal temperature with extraordinary regularity. If the monthly deaths from the disease be plotted and compared with the monthly temperature it will be found that the curves are almost parallel, the typhoid fever rising with the temperature after about two months, an interval representing the incubation period of disease and the time which elapses before death. Where the temperature curve is acute, that of the mortality follows it, whereas in a mild climate, the distribution of the disease is more even. In the southern hemisphere both curves are reversed. We have elsewhere shown that these phenomena are so constant and so universal as to suggest in the strongest manner a direct relation between temperature and typhoid fever; and our theory of this relation is as follows:

"The bacteriology and the etiology of typhoid fever both indicate that its causal agents cannot be abundant in the environ-

ment during the colder seasons of the year. The germs of the disease are carried over the winter in the bodies of a few patients and, perhaps, in vaults or other deposits of organic matter where they are protected from the severity of the season. The number of persons who receive infection from the discharge of these winter cases will depend, other things being equal, upon the length of time for which the bacteria cast in the discharges into the environment remain alive and virulent. The length of the period during which the microbes live will depend largely upon the general temperature; as the season grows milder, more and more of each crop of germs sent at random into the outer world will survive long enough to gain entry into a human being and bear fruit. The process will be cumulative. Each case will cause more secondary cases; and each of the latter will have a still more extensive opportunity for widespread damage. In our opinion the most reasonable explanation of the seasonal variations of typhoid fever is a direct effect of temperature upon the persistence in nature of germs which proceed from previous victims of the disease." (Sedgwick and Winslow, 1902.)

In cities having polluted water supplies there was an interesting departure from the normal seasonal distribution of typhoid. We found the normal maximum in September or October; but in some cases there were also secondary maxima in the fall and spring as shown in the curves for Chicago. These high death-rates in the cooler months were at first puzzling, and such instances have obscured the usual seasonal variations and led some sanitarians to deny the existence of any relation between typhoid fever and temperature. As soon, however, as it appeared that curves of this type were associated with polluted water supplies, their significance became clear. The fall and spring epidemics coincide with the fall rains and the spring thaws, which wash infecting material from vaults on the banks, or through storm overflows, into the water supplies, carrying it fresh and virulent to the consumers below. A seasonal distribution of this sort appears to be characteristic of many communities drinking from unprotected surface waters; and it was found by us in this country in Chicago, Cincinnati, Newark, and Philadelphia. On the other hand the large majority of cities, including Atlanta, Baltimore,

Boston, Charleston, Denver, Mobile, Montreal, New Orleans, New York, St. Paul, San Francisco, and the District of Columbia showed a close and constant relation between the temperature and the seasonal prevalence of typhoid fever.

It is obvious that the difficulties of tracing the path by which prosodemic typhoid spreads in the individual case must often be insuperable. In a crowded community there are so many possible modes of transfer in each separate instance that it is generally impossible to demonstrate the chain of infection, as may often be done in an epidemic inflicted on a number of persons at a definite time and by a single common cause. As intermediate vehicles of the disease, we may have soiled clothing, or bedding, or the woodwork of privies, water, milk, celery, lettuce, or fruit. Food, fingers, and flies offer an alliterative summary of the most common agents. The one thing upon which we can fix our attention with certainty is the common point of departure. Every germ of typhoid fever, whatever its subsequent history, originates in the body of a typhoid patient and leaves it in the excreta. Every case of typhoid fever is due to the presence of excreta on food or fingers, or in some other place where excreta should not be. Filth is the fundamental condition for the spread of typhoid fever; cleanliness the universal panacea for its eradication.

Exactly how much responsibility ought to be assigned to each of the individual factors it is not always possible to say, and we need, therefore, to be particularly careful not to jump too hastily to conclusions. As regards flies, for example, we must remember that while these are unquestionably important vehicles in the spread of typhoid fever, the striking fact remains that the time of greatest mortality from typhoid fever in Massachusetts is not such as to justify, offhand, a belief that flies are the principal vehicle of that disease in this state; for, while typhoid mortality reaches its maximum about the middle of September, a fact which demonstrates that the germs are received by the inhabitants in greatest numbers or under most favorable conditions at some time in August, it is generally believed that September is often, if not always, the worst month of flies. On the other hand, the truth may be, of course, that even if flies are more *numerous* in September they are less *active* than in August, and we must therefore

be careful not to dogmatize on either side without sufficient evidence. One fact which stands out with especial clearness the longer we study the subject is that in spite of all that may be, and has been, said to the contrary, *typhoid fever is a contagious disease.* Instead of saying, as is often said, that "typhoid fever is infectious, not contagious," we need to say to-day that "typhoid fever is both infectious and contagious"; and, doubtless, it is in part for this very reason that it has been found so difficult to exterminate.

The conclusion of the whole matter is perfectly clear. Dirt and disease go generally hand in hand, and the importance of disinfection as near as possible to the source of discharge becomes more and more obvious every day. It is plainly wasteful as well as dangerous to allow disease germs to escape from their original sources of supply and become distributed in the environment. Extraordinary pains are therefore requisite in order to destroy their dragon's brood at the very outset, and we cannot help feeling that boards of health are here often remiss. Too often boards of health content themselves with routine work; too often they are more careful for their own political lives than for the lives of the people whom they serve. What we greatly need at present in many of our cities and towns is greater *activity* and *aggressiveness* on the parts of boards of health, especially in respect to sanitation as opposed to hygiene, so that disinfection shall be more carefully done, so that polluted wells, which are still frequently in evidence in many of our thriving towns and cities, shall be closed up, and so that privy vaults and other primitive methods of disposal of excreta which are unfortunately too characteristic of American cities and towns, and whose disappearance is a sure index of effective civilization, shall be cleaned up and done away. Meantime, all good citizens should uphold boards of health in all their reasonable activities, and contribute as far as they can towards that enlightened public spirit which shall insist upon a higher standard of cleanliness in all our cities and towns. But even all these things are not enough. We greatly need an extension of power in our state sanitary authorities so that these shall be not merely advisory and judicial, but shall have, besides the power and duty of investigating and reporting, some measure of *control*, so that when

local authorities are neglectful or powerless, a higher authority may step in and protect the lives and health of the people; for local carelessness, neglect, or ignorance may, and often do, entail the widespread injury of states and even nations. In Massachusetts, for example, we ought to have some system of district sanitary or public health inspectors, and some system of centralized authority similar to that which we have in the state medical examiner system, a system which has replaced with so much advantage the antiquated "coroner" system of former days.

This is an old story. Yet as long as conditions remain unimproved it is a story which must again and again be repeated. The authors of this paper presented a communication bearing a similar title before the American Public Health Association at its New Orleans meeting in 1902, with the following conclusions (Sedgwick and Winslow, 1903): *First*, that in the state of Massachusetts and in some of the larger cities of the United States the public water supplies are now relatively unimportant as vehicles of typhoid fever.

Second, that in cities having pure water supplies the annual curve of typhoid fever mortality closely follows that of annual temperature.

Third, that in urban communities supplied with pure water there still remains a typhoid fever tax of from 15 to 25 deaths per 100 000 population. (To this we now give the name *residual typhoid*.)

Fourth, that this tax is due, not to any peculiar condition of soil, locality, or climate ("endemic" factors), but to incomplete disinfection of typhoid excreta, with subsequent infection of various articles of food and drink. These factors, when acting upon a few or many persons at one time, may cause obvious epidemics, sometimes large, through generally small; but more often the infection in moving from one point to another follows various, and often obscure, routes for different victims, and hence may be described as *prosodemic*.

Fifth, that the only remedies for such prosodemic typhoid are absolutely thorough and universal cleanliness, and especially a thorough disinfection of all excreta.

The same conclusions may serve for the present communica-

tion. and we propose to reiterate and proclaim them at convenient intervals until the public is aroused and educated to that cleanliness which is next to godliness, and our national excess of typhoid fever ceases to be a discredit to American civilization.

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DISCUSSION.

THE PRESIDENT. The paper is before you for discussion, and I will call first upon Mr. Lochridge.

MR. ELBERT E. LOCHRIDGE.* Mr. President and fellow-members, I have been very glad to hear everything that Professor Sedgwick has said in regard to typhoid, for I believe that in the press and in the general feeling of the majority of the citizens, not only of this state, but of every state and of every city, the opinion prevails that water not only carries typhoid, but that it is the chief carrier of typhoid. I do not want, in any remarks which I may make, to in any way disparage the danger from water-borne typhoid but the care of water systems, of water supplies, and the general elimination of grossly polluted supplies have really brought about a condition that may be considered as comparative immunity from typhoid epidemics coming from water in many cities.

We have had in Springfield during this past summer — and the situation is not as yet entirely cleared — an epidemic which will bring out this fact very plainly. We have a water supply there of which none of us is proud, and I believe that two thirds of the citizens of Springfield would rather believe something bad of the water than not; so that on the outbreak of an epidemic of typhoid this season, the water was at once blamed.

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Out of the first seventy cases which occurred, I believe the families were supplied with milk by thirty-five different milkmen. This, together with the fact that the number of cases was so small compared with the number of families which were supplied by these milkmen, very effectively removed the milk from the suspicion that it was the carrier of the disease. As a practical water-works man I was extremely interested in the situation, and had all the cases reported to me from the board of health. This was done so that any indication whatever that the water was even slightly to blame could be carefully traced. With the elimination of milk as a possible source, and the general feeling in the city that water was the cause, I undertook to investigate and go thoroughly into the causes of the epidemic. The many statements which have been made that typhoid epidemics are usually due to water or to milk, coupled with the fact that our water supply was not in good repute, was, I believe, responsible for the feeling, not only of suspicion, but of certainty in the minds of most people that the water was to blame.

The local board of health have a routine system of investigation of every case of typhoid. On the cards which they prepare are blanks where may be recorded the usual data, including the source of water supply of the patient, the milk supply, the name of the physician, the date on which the patient went to bed, address before attack, occupation, etc. On looking over the cases one very marked thing stood out at once, and that was the *names* of those who had taken the disease. I followed this up and noticed that the epidemic was confined almost entirely in the earlier stages to residents of one particular section, and that this was the section in which the foreign element lives. Later, as the cases began to multiply, our board of water commissioners instructed me to investigate the epidemic. At about that time Dr. George B. Magrath, now the acting secretary of the State Board of Health, who is present to-day, came to Springfield, and we conducted our investigation along parallel lines.

It was at once seen that the key to the situation was not contained in any of the data which we had, although the data had been rather carefully prepared along the usual lines. It was then determined that the first work should be directed to the securing

of more information. Nothing stood out as the cause of the fever from the reports which were in. I mention these facts because

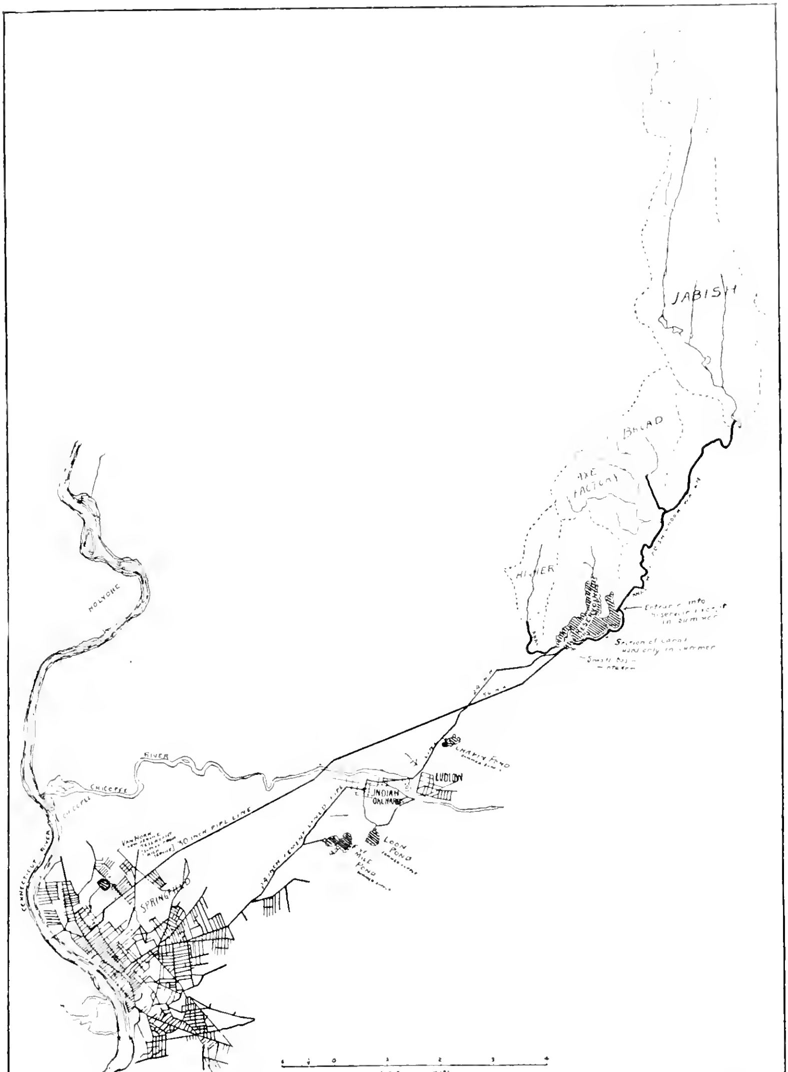

FIG. 1. GENERAL PLAN OF SPRINGFIELD WATER SYSTEM.

as water-works men you may all have to deal with some such epidemic and with some such feeling as we have had, for with the cause of the epidemic very obscure in its earlier stages the general sentiment was in Springfield that the water supply was to blame. This further investigation was conducted along the lines of getting additional information, which was tabulated and worked out independently of the information submitted by the local board of health, and data from each of the sources considered.

I will attempt to give you a brief outline of the situation as it stood at the beginning of this study.

Before you (Fig. 1) is a map of the Springfield water system. Lying to the east of the city proper is the village of Indian Orchard, which is a part of the city. Just beyond Indian Orchard is the village of Ludlow, which has a population of 3 500 people; Indian Orchard has a little less than 5 000. All of Indian Orchard and Ludlow have the same water supply as the city of Springfield. Our Ludlow reservoir is four miles beyond the village of Ludlow, and is practically twelve miles from the Connecticut River. The two mains which we have supplying the city with water pass through these villages to the city, as shown on the map.

To show what our water supply is, I will say that we have a storage reservoir of about 1 800 million gallons, which is fed by several small brooks immediately adjacent to it, and by one that is larger, Jabish Brook, which is diverted through a canal eight miles in length to the reservoir. These are shown on the map. In the summer season the water in the reservoir becomes absolutely undrinkable. It would be impossible to make the people drink it if you gave it to them; they would drink anything else they could get. So in the summer time Jabish Brook is diverted around the reservoir to a small basin containing not over three days' supply.

We have also, east of the city and near the villages of Indian Orchard and Ludlow, three ponds which are situated in a sandy plain and are without tributaries of any nature. These are used only in the summer and for the purpose of making up the deficiency in the amount necessary to supply the city over the summer flow of Jabish Brook. One of these ponds (Five Mile) lies between Springfield and Indian Orchard. The largest amount of water

is taken from this pond. The second (Loon Pond) lies just at the village of Indian Orchard, and the third (Chapin Pond) between the Ludlow reservoir and the village of Ludlow.

After about the first of August every summer our supply consists of the direct flow of Jabish Brook, unstored, supplemented by water pumped from the three ponds just mentioned. Between the Ludlow reservoir, which is at sufficient elevation to supply water to the city by gravity, and the city are two mains. All of the water from the ponds is pumped directly into one main at points which can be easily seen by reference to the diagram. This main is the one which supplies, in large part, these outlying villages.

The typhoid epidemic, or the first number of cases with which we had to deal and which are marked in heavy dots surrounded by circles on the map (Plate I), came down in the ten days following the 15th of July. If you will notice the larger number of them, near the west edge of the map, you will see they were confined, with four exceptions, to one district, and this is the foreign district of which I spoke. At that time it became necessary to use the summer supplies. Owing to the nature of the system, all of the hill section, all of Indian Orchard and Ludlow, are supplied by the water pumped from the ponds, which constitutes about 65 per cent. of our supply after that date. The north end, extending to the Chicopee line, is supplied from the other main which comes into the city on Carew Street and supplies all of the down-town district. There is also a low-service system, water for which comes from this Carew Street high-service main, and this service supplies in parallel pipes the district lying near the river, and in general the same down-town district supplied by the main pipe just described.

With the increase in the flow of Jabish Brook following the midsummer rains, the pond supplies were shut off, and at such times the water supplied to all of the hill and Indian Orchard districts was again unstored brook water. Following the dates of such change, which involved a complete change in the source of water furnished these districts, there was absolutely no change in the typhoid situation. We had, then, a knowledge of just which parts of the city were supplied with each of the different

kinds of water and the dates on which they were thus supplied. You will then see we had five different sources of supply during this time, and with the knowledge of the dates of each, had any one of the supplies been infected we would have known the locality in which to look for the infection; or on the disease breaking out in a given locality, we could look to a particular source supplying that locality on that date. We found, however, that there was no such comparison. Part of the cases were on the high-service and part of them on the low. The distribution of the earlier cases was not a general distribution which you would get from a water-borne infection, but a distribution on a few streets where the general sanitary conditions were the worst existing anywhere in the city.

Later, the cases which are indicated on the map in heavy dots came down. This map is complete to September 20. If the cases since that date should be added we would have half as many more, confined largely to the same locality, but with some scattering.

The data which we collected were tabulated and we were able to determine with greater accuracy the true date of onset of the disease, that is, the earliest date which it was possible to find that a person had been sick.

A great many patients will be what are called "walking" cases, — patients who will not go to bed for three or four weeks; and we found, as far as the tracing of the time was concerned, that the date of going to bed, which was supplied by the local board, was of very little value.

I am not going into the modes of transmission of this disease in Springfield except very briefly, as Dr. Magrath will cover that in a few minutes, but I want to call attention to this diagram (Fig. 2), which brings out the dates on which, according to our revised data, the epidemic was made manifest, that is, the date of onset.

The earlier cases with which we had to deal were in July, at a time when we were using stored water from our main reservoir. On the earliest date there was a case on the hill (No. 4), which in locality would be right to throw suspicion on the pond supplies, but inasmuch as the epidemic was well started before the pond

MAP OF SPRINGFIELD, MASS., SHOWING LOCATION OF TYPHOID FEVER CASES FROM JULY 15 TO SEPTEMBER 20, 1905.

supplies were used, and also as the water supply changes already referred to did not affect the distribution of the cases, it could be seen that water could not be considered as a cause. Every possible suspicion which in any way could be thrown on the water was studied, but all additional data pointed away from water and to other causes.

The study made of the individual cases brought out a peculiar fact as far as locality was concerned. With one exception, in all of the earlier cases, I believe the rent paid for the house in which there was a typhoid patient did not exceed $12 a month, and in a great many of them the rent was from $5 to $6 a month, this bringing out the nature of the locality in which the disease broke out. The streets from the railroad through to about Congress Street are filled with a foreign population, principally Russian Jews, Syrians, Irish, and some Italians, while Water Street and the adjoining region is largely Italian. The first cases were largely confined to this class of people, and as the people could not talk English in most of the cases, we had the hardest kind of a time getting any information.

We found that in this earlier group, practically all of them had

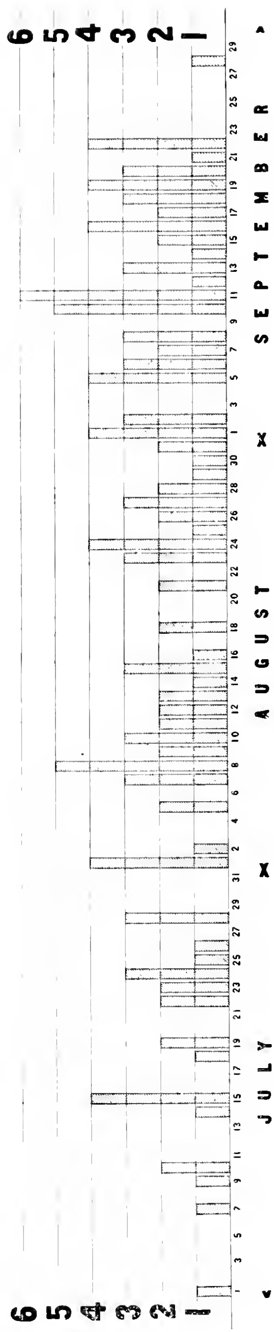

Fig. 2. Diagram Showing Occurence of Typhoid Fever Cases in Springfield, July–September, 1905.

gotten their vegetables from one man. Just what the infection of his vegetables was it would be very hard to say. His wife was sick with a slow fever, but with no indication, as far as the doctor's diagnosis was concerned, that it was typhoid. There were at least three cases of typhoid on his route. Then we traced the method of handling the vegetables. He went about in an open wagon carrying vegetables which he purchased both from large dealers and also picked up from farmers, — in any place where he could get them cheap, — and the handling of the vegetables by customers and putting them back on the wagon was found to be the universal practice everywhere in the streets in which he dealt.

From that point on the epidemic took on another nature, and we have called it a contact epidemic. This same vegetable man probably did not cause more than these first cases, but the families in which these first cases came were peddlers, men who passed through the city vending meats, vegetables, fruits, etc., and men who ran small stands.

In taking up the technique of the investigation, I think it would be well to tell how we studied it, for if any of you are so situated that you can get no help at all from your local board of health, you may want to have some means of procedure. If the local board will simply make a statement that your water supply is to blame and let it rest at that, you may want to know how to get at the situation. Three men who understood the nature of the transmission of typhoid were brought to Springfield, and worked under Dr. Magrath's and my direction, Messrs. R. E. Tarbett, W. H. Lalley, and H. C. McRae. They worked faithfully and hard and their assistance was an important factor in finding the cause of the epidemic. These men went from house to house and took note of all the conditions; and the conditions which they found were a good deal worse, and might be described even more vividly, than some of the descriptions which were given in Professor Sedgwick's paper. The uncleanliness of that region was very manifest. In the shops where buns were for sale we found them so covered with flies that you would have to brush the flies away to see whether they were buns or whether they were bananas; and the general method of handling what

was exposed for sale was extremely dirty. I must not tell more than that, for Dr. Magrath will give you a number of instances. In general, it can be said that it was a filth epidemic; the seed was planted on very fertile ground.

If we go back into the study of typhoid, we shall find that at one time it was believed that piles of filth bred disease, the typhoid germs multiplying and growing in the piles of filth. Later, when we began to know something more of the germ theory, that all passed away and there was a reaction, and it was said that filth did not cause disease; no matter how much dirt there was, it was not disease and could not cause disease. I think now we are ready to go almost back to the older theory. It is true that germs do not originate in these piles of filth, but they are pretty much at home there, and if they are handled and brought into contact with food or with drink, you will get typhoid from them.

The later stages of the epidemic raised points which in the popular mind were the hardest thing to understand. After about a month or six weeks, we found the disease beginning to get into the better families and spreading out over the city. The better class of people objected to having it said that the epidemic was caused by peddlers, claiming that they did not patronize them, and did not care to have any connection with them mentioned. Even a casual glance at the epidemic, however, brought out an important fact. In the earlier stage the carrying of the infection was probably in that manner. In the second stage not only in this manner, but also in many other means of contact, and in the later stages the means of furtherance could be counted by the dozen instead of by a single one as in the earlier cases. Few families know the history of all of the fruit, vegetables, and other food brought to their homes, or the movements of their servants when not on duty in the house.

With regard to the village of Ludlow it may be well to say a word. Ludlow is a manufacturing town, with a population largely, almost entirely, foreign. In this town through the entire summer there was not a single case of typhoid fever anywhere on the mains, and at the present time I believe there are but three cases in the village, and two of those are entirely off the water supply. Indian Orchard was also exempt. I mention this

merely as a confirmation of the general statements which I am making in regard to the transmission of the disease.

And another very marked thing was that these localities were not localities where local or small filters were used. That is a point which is brought up at once. It was given as a reason that a certain class of people were exempt, that they filtered the water, or that they didn't use the city water; but here was a region with a population of over 8 000 who did not have filters in their houses.

Taking up the better localities, you can see at the eastern edge of the map that the so-called McKnight district was practically exempt. The Forest Park district, which is also occupied by the better class of residents, in the southwest corner of the map, was entirely exempt, and in the northern section, the Brightwood district, which is occupied largely by the better laboring class, I believe there was only one case of typhoid fever. These localities represent very diverse water-supply conditions during the period of the epidemic. The region nearest the water supply, which should, in the case of a water-borne epidemic, be first to show its effect, was entirely exempt. The region most directly supplied steadily by Jabish Brook water was entirely exempt. Two other regions supplied alternately by pond water and Jabish Brook water were entirely exempt, while the remaining portion of the city, representing no new sources or no different sources, have in them a large number of cases. So on the face of it you would say at once that it was very simple; but when you come to face the actual situation of a general belief that it is the water, and an unshakable belief on the part of the physicians that it is the water, you have to go into it pretty thoroughly in order to show that it was not. However, we did not go into it to show that it was not the water, but to find out the real cause.

Referring again to the diagram, you will notice the almost intermittent action; that is, days on which the typhoid breaks out, then will follow a lull, to be followed by another outbreak. No two of these groups of cases were supplied by the same water, nor had the same water conditions. You will note that they followed pretty closely the incubation period; that is, each period of cases made new foci and from these foci developed further cases of typhoid, so if we were seeking a cause we should seek a

cause for each one of those outbreaks. And that can be seen if you go into the occupations of the first group and follow it right through from group to group.

In regard to seasonal or residual typhoid which has been mentioned, I want to say a word, and that is this: With the elimination of water-borne typhoid we still have this residual or seasonal typhoid. Every city has it, and there is a cause for it and it is a perfectly natural cause; that is, the germ must come from a typhoid patient and must be taken into the alimentary canal of some other person. That is all that is necessary for typhoid, and in all of this residual or seasonal typhoid, every one of the patients must have gotten the typhoid in that way. I believe that this epidemic at Springfield can very clearly be shown not to have been caused by water, but to have been caused by contact in various ways, and I think that in this epidemic we have a magnification of the cause which brings about seasonal typhoid. It was on a large scale, — there were altogether, I think, two hundred cases. Those cases were from the causes which are active each year in producing seasonal typhoid, but inasmuch as the disease was first planted in a district which supplies food for other districts, and in a district which is very dirty, we have the ideal conditions for a very large seasonal typhoid.

Dr. George Burgess Magrath.* Mr. President and members of the Association, I wish to thank you most heartily for your hospitality, and for the privilege of listening to the paper of the afternoon and of participating to some slight degree in the discussion of a theme which is of such great interest alike to the sanitary engineer, the biologist, and the physician. Professor Sedgwick has covered the general subject so exhaustively that there is very little which I could possibly add so far as the general aspects of this important problem are concerned; and in what I have to say I shall deal mostly with certain aspects of the epidemic of this year in Springfield, concerning which Mr. Lochridge has told you a great deal.

You will, perhaps, bear with me, however, if I preface what I have to say by some general considerations with regard to acute infectious diseases.

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No department of medical and biological science has shown a greater increase in the sum of knowledge in recent times than that of epidemiology, or of our knowledge of the cause of diseases. The application of this increase of knowledge to sanitary science and for the protection of public health has been most prompt and, as you all know, is of the greatest importance to-day in the protection of our communities from the spread of acute infectious diseases.

If one were asked what is meant by an acute infectious disease, what is meant by a contagious disease, I think he would have to answer somewhat as follows: That by an acute infectious disease we mean one the cause of which is a micro-organism, whether animal or vegetable it matters not, which enters man or the lower animals as a parasite, and, growing, produces in the course of its growth, injurious substances of one sort or another. These poisonous substances cause abnormal anatomical conditions, the outward expressions of which are the symptoms of disease.

Now among the infectious diseases, the germ diseases, — and, of course, our whole conception of the nature of those diseases has been modified within less than a generation by the discovery of micro-organisms, and the identification in many of the infectious diseases of some form of organism which is specifically present in each, in many instances producing changes characteristic of the disease, — among this large group, there are certain diseases which are more easily communicable than others, which are much more easily transferred from one individual to another, than are other diseases; and these are commonly known as the contagious diseases, although there is not necessarily any sharp line dividing one group from the other. Professor Sedgwick has pointed out that typhoid fever under certain conditions is so easily communicable, or is communicated so directly, as to be rated as a contagious disease. But if we contrast with typhoid fever smallpox, scarlet fever, measles,—possibly, also, diphtheria, —we see at once that there are certain diseases which are so easily acquired that it is necessary only to enter the room in which is a patient suffering from one of those diseases, in order to render a susceptible individual, one who has not had the disease or is not otherwise protected from it, extremely likely to catch it.

Now, the first diseases mentioned, *i. e.*, scarlet fever, smallpox, and measles, for a long time, although carefully studied, presented no etiological factor clearly demonstrable, — that is, no definite germ was found in the lesions produced in the course of those diseases. Latterly, there have been recognized, certainly in scarlet fever and smallpox, bodies which belong not to the bacterial group or vegetable group of parasites, but to the animal, and these bodies are capable of producing spores, minute protoplasmic particles, which are easily passed about in the air and communicated or transmitted from one individual to another by the very air that we breathe. That seems to explain why in certain diseases transference from one to another is so easy. Of course, among the bacteria there are those which are more readily killed by sunlight and by exposure to degrees of temperature unfavorable to their development or growth than are others; so that amongst the bacterial diseases there are some which are more easily communicated from one individual to another than are others. In addition to these differences, partly the inherent characteristics of the organism, partly its ability to live under unfavorable conditions, there is the set of differences which obtain according to the way in which the disease is acquired. An organism which, in order to produce its lesions, must be taken into the mouth or nose and into the lungs, is an organism which may be, and is likely to be, one which can be transmitted by the air in dust, and will produce a disease which is easily communicable. That is, there are differences in the way in which these parasites or germs enter the body. Those which enter through the mouth, through the lungs, through the respiratory system, produce diseases which are readily acquired. Those which enter the body through the digestive tract, on the other hand, of which cholera, dysentery, and typhoid fever are examples, are diseases which are not acquired by mere proximity, or by the inhaling of the air which has been breathed by an individual suffering from them, as are smallpox and scarlet fever.

There is still another group of diseases in which the organism must enter through the skin, through the sting of an insect, of which malaria and yellow fever are examples.

Now with the increase of knowledge in regard to typhoid fever,

it has become apparent that there are modes of transmission or vehicles for the entrance of the organism into the body (and it must enter through the mouth and be swallowed in order to produce its effects) other than those which for a long time have been recognized as the more prominent, *i. e.*, water, milk, and shell-fish. In other words, it is, perhaps, necessary that we hold in suspicion every article which may be put into the mouth. Such a vehicle may be fruit or vegetables or bread or candy; anything, really, which may pass the lips must be looked upon as a possible conveyence or vehicle for contagion, bearing in mind, of course, that typhoid bacilli will not withstand conditions markedly unfavorable in point of dryness and temperature, as will some of the other forms of parasites, those which produce the spores and are transmissible by the air and dust.

Passing rapidly from such general considerations to the specific instance of this epidemic, Mr. Lochridge has explained to you why, after a careful review of the situation, it seemed improbable that all the cases of typhoid fever in this outbreak should be referable to the water supply. There remained, after you subtracted from the total number of cases those which could be referred to the seasonal or "residual" occurrence, a very considerable number of cases, in fact a very large percentage, which we found distributed focally. Mr. Lochridge has pointed out to you that the distribution of the cases over the city is of some sociological significance.

Upon this map, Plate I, are indicated in dots surrounded by circles cases which occurred during the last two weeks of July. From the 15th to the 28th of July there were some sixteen cases. These sixteen cases had the geographical distribution indicated. It is apparent at once that they are most numerous in the regions which Mr. Lochridge has described as being those occupied by a foreign population, largely by Jews, Syrians, Greeks, and some Italians. This peculiarity of distribution of the early cases, which was continued as time went on and the cases increased in number, this increase taking place in localities where the dwellings were shabby and the rate of rent low, led us to inquire more closely into the domestic conditions, the personal habits, and the physical surroundings of the people living in these localities.

It would be difficult to describe with accuracy and sufficiently forcibly the conditions which prevailed in the Jewish quarters. I have never seen any more marked exhibition of uncleanliness, not to say filth, than prevailed in those quarters. The people were very closely crowded in the houses, and they were very careless with regard to the disposition of their excrement. Open privy vaults to the number of forty were found on two of these streets, but the inhabitants didn't always take the trouble to use the vaults. There were many children in this district, and, of necessity, in accordance with their standard of living and decency, the distribution of excrement was rather widespread. To a certain extent the same conditions prevailed in all of the regions where typhoid fever was most prevalent. These seem to be the remains of Old Springfield. Tucked away in behind the higher and better buildings, old houses, poorly constructed, poorly equipped, and with imperfect plumbing or no plumbing at all, still exist. In one of these regions a number of negroes live, and in another region there is a "poor white" class. Along Water Street are many Italians, and in the progress of the epidemic many more cases developed in this district than are shown upon the map.

The elimination of water and milk as vehicles of contagion, rendered possible by careful study of all the conditions, showed that we must inevitably be dealing here with other means of infection, some of which Professor Sedgwick has referred to this afternoon. First of all, within the families opportunity existed for contact spread of the disease. There is no question about it. Given one case in a family of seven or eight individuals living in three rooms, with conditions of extreme filth in the kitchens and living rooms, with no precaution whatever taken to prevent contamination of food by filth, it seems to me that conditions were ideal for contact spread. But that would not, of necessity, relate cases in the dirtier districts with cases occurring elsewhere in a population comparable with that in such regions.

The incidence of these cases in point of time, the fact that there occurred in all of this region in the last two weeks of July and first two weeks of August cases of typhoid fever, led us further to inquire whether there was any vehicle which possibly could be

operative in these different communities at the same time or nearly the same time. We were continually impressed with the fact that it was among the poorer people and the dirtier people that the disease was spreading, and, of course, there was the possibility of contact spread elsewhere. I think it is undoubtedly true that typhoid fever had existed here from early in the spring, that cases which nearly overlapped in point of time existed in this region, and one, at least, existed in this region as early as April, and that case had access to, and used, an open privy vault, the contents of which were not removed. The houses in the vicinity were all poor shacks, with unscreened and broken windows, and, if we are entitled to admit in the spread focally of typhoid in these regions the possible instrumentality of flies, there certainly existed the opportunity.

In this connection it is worth mentioning — and this was the result of rather a careful study of the region from day to day — that in this quarter are venders of all sorts, bakers, green grocers, and dispensers of fruit in hand-carts, whose routes take them in and out through these streets, off along through the Italian quarter, and to some extent up through State Street and over through Walnut Street, and down into the part of the town known as the Watershops district. It was perfectly manifest to us that venders of various sorts, selling through this region where most of the cases occurred, in the earlier part of the summer, also did business in the parts of the town where typhoid subsequently became rather prevalent. The machinery existed for the conveyance of the disease in that fashion to some extent. Whether that really was a factor is, of course, bound to be a matter of some speculation. There is no direct evidence; it is all circumstantial evidence at best, but the way in which these hucksters sold their goods certainly impressed upon us the fact of the possibility of this mode of spread. The vender of fruit and vegetables starting in here in the morning (he might or might not be a resident of that quarter, although three or four peddlers of that sort did live in that quarter), starting in on one of these streets, would go from house to house; the women would come out and overhaul the stock and select what they wanted and purchase it, and the wagon would go on to the next house. Now there was enough

typhoid in and out through those streets to have rendered it certainly possible, if not probable, bearing in mind always the habits of the people, the fact of personal uncleanliness, the fact of a considerable prevalence of typhoid among children, many of them infants, that contact infection should take place; that is, for the direct passage of infected filth from hands to these wares to have occurred. Furthermore, all through these streets are small basement shops in which are exposed for sale, as Mr. Lochridge has stated, bread, cake, pastry, and green stuff. At the time of the year when I was in Springfield the latter consisted mostly of apples and, to some extent, peaches and pears, cabbages, and so on. In the earlier part of the summer, of course, there were lettuce and berries of various sorts. The wares in these shops were handled in very much the same fashion as those in the peddlers' carts, that is, people who were going to purchase would overhaul the stock and select what they wanted. This as a medium for local spread I regard as of some importance, and the venders as of importance, also, in the spread of the disease from one neighborhood to another. The people living here are of such sort as to render them patrons of the small venders with push-carts, which is not true of the inhabitants of other districts. These carts are not to be found up in the McKnight district, or in the Forest Park district.

One other point. The Hampden County jail is situated here (Cases 8, 23, 24, 102, 103, and 116), and in the first two weeks of what we may speak of as the epidemic, which period coincides with the last half of July, there occurred one case of typhoid fever, and within a week of that time two others in the jail, all on the same cell tier and on the same side of the cell stack. This occurrence of the disease in a population which was largely immobile, the three cases which I refer to occurring amongst long-term men, — no one of them had been in the jail less than four months, and the most of them were there for a two years' sentence, — seemed to offer a somewhat anomalous fact. Cases subsequently occurred to the number of six, all among men who had been in the jail for six months at least, and some of them for a year or more.

Now, how did the disease get there? The jail is an exceedingly

well-governed institution. It is exceedingly clean, one of the best medical men in Springfield is the attending physician, and I have never visited an institution of its sort where the sanitary conditions were of any higher order than they are in the Hampden County jail. The fact, however, must be recognized that prisoners have ways and means of getting certain things that they are not supposed to get. They are allowed in the Hampden County jail chewing gum and cough drops. Tobacco is not allowed, but tobacco does find its way into the Hampden County jail, as I guess it does into every reformatory institution. Some of the short-term men, men in for a few days, are employed on the outside of the building, around the jail grounds, taking care of the premises, and they were in the habit after raking up the ground of taking the débris of various sorts over to the city dump, which lies at a distance of about one hundred yards easterly from the jail. Incidentally they would look over the débris and bring back cigar butts, and, probably, anything else which they thought worth taking away, and which could be put into their pockets. This statement as to their bringing back cigar butts is on the testimony of at least three men who had typhoid fever and were taken to the hospital. I do not offer this as an explanation of typhoid fever in the jail, but I do think that jail walls are not strictly impervious, and that something which might act as a vehicle for the transmission of typhoid could have found its way into the jail. We don't know anything about it, and I merely mention it as an anomaly in this epidemic. Of course, there is an explanation for it, and I think it may be along the lines which I have intimated.

All of this, it seems to me, goes to show that there can occur in our cities epidemics of typhoid fever which are not attributable to the water supply, or to milk, but which occur because, as Mr. Lochridge has stated, inflammable material or a fertile soil exists upon which infection will thrive if it happens to get planted. It became so planted in Springfield, and upon a soil favorable to its spread. The fact that typhoid fever had not spread in these regions before is no objection to this as an explanation. A part of a city in which the buildings are far below, we will say, the requirements of modern building laws, is a permanent menace to the city from danger of fire so long as it is there. The regions of

the city of Springfield in which the epidemic thrived are those in which the sanitary conditions were the poorest, where the advance of civilization and sanitary improvement had not gone far enough to eliminate the privy and to render imperative such improved conditions within the houses as would have removed from the city the soil upon which the epidemic spread.

Prof. C.-E. A. Winslow. We may well be proud of the leadership of Massachusetts in sanitary matters and especially in the matter of water supplies. I think it may be said that a man can go to almost every city and town in Massachusetts and drink from the public water supply with safety, which certainly cannot be said of any other state in the Union. That having been accomplished, however, we cannot afford to remain satisfied with our laurels. We must move onward, and having wiped out here the highest death-rates from typhoid fever, ranging from 25 to 125 per 100 000 in cities having polluted waters, it becomes us to turn our attention particularly to the residual typhoid, the 15 to 25 deaths remaining, and to endeavor to find out what causes that.

We have had a splendid object lesson as to residual typhoid in this Springfield epidemic. It has been shown most conclusively, I think, by Mr. Lochridge and by Dr. Magrath, that the Springfield epidemic is not due to water. Of course, in studying the cause of any phenomenon it is always easier to fall back on the cause of other similar phenomena, than to try to find out a new one actually operative in the particular case. It was easy enough, and perhaps right enough, twenty years ago, to say that typhoid fever was due to the water supply, but that explanation will not serve in many communities to-day.

When we find, as we do on an inspection of the typhoid death-rates, that we still have 15, 20, or 25 deaths from typhoid per 100 000 of population, and when we look abroad and find that in England and in Germany they have death-rates from typhoid ranging perhaps from 3 to 10 per 100 000, it is time that we asked ourselves the reason. If, as has been brought out in the paper and the discussions this afternoon, typhoid is essentially a filth disease, a disease which is carried by excreta getting where excreta should not be, it is obvious that we must ask ourselves

whether we are a dirty people, whether we are a dirtier people than the Germans and the English.

Of course we have in our cities to-day an extremely difficult problem to meet. We haven't an essentially American population, — a Yankee population, — but we have a population including groups of Greeks and Syrians and Armenians and Italians, people from the south of Europe who have come from unsanitary conditions and who are accustomed to unsanitary conditions.

One of the points which has greatly interested me in the history of the Springfield epidemic has been the comparison of the typhoid fever rate with the social condition of the population. It is a new thing, I think, to connect a typhoid epidemic with low rents, but it appears to have been justly done in this case. That is, the typhoid epidemic is there because of the dirty surroundings which accompany low rents. To be sure we do not have typhoid epidemics everywhere where there is filth, and that argument will always be brought up in a discussion of this sort. But, as the gentlemen who have spoken have said, filth is the inflammable material. It does not explode until the match is applied to it. But it is so fatally easy to apply the match, so fatally easy to introduce the one case of typhoid fever which will spread like fire through the filthy region, that we must regard the filth as always a potential agent in the transmission of typhoid fever.

Furthermore, that one case need not be a recognized case. We have numerous examples of walking typhoid, cases which, perhaps, are never known as typhoid fever, where the persons may walk about and feel poorly and, perhaps, have a little diarrhea for three or four weeks and then may get well without ever knowing that they have had anything but some little summer trouble; and yet they have had typhoid fever and have been all the time spreading the germs more actively than if they had been actually confined to bed with the disease. We know that typhoid germs may be present in the urine of a typhoid patient after recovery, in some cases for months, so that a person who has become apparently quite well may still be going about sowing the seed. In view of these facts the one thing for us to do is to see to it, so far as we can, that there shall be no accumulation of inflammable filthy material ready to be set aflame at any moment.

Another point which interested me particularly in what Mr. Lochridge said was the spread of the epidemic to the better localities in the city. That will inevitably occur. It is true nowhere more than in sanitary science that we are all members of one body, and that if one part of a city is allowed to be filthy, other parts of the city are sure to suffer. If there is typhoid infection in the dirty part of the city, that will get on clothes or on fruit, or be brought into the best houses by servants who have mothers and brothers and sisters in the slum districts whom they go to see, as I have found in two or three cases of small obscure typhoid epidemics. These servants perhaps go into the filthy districts, where they make the beds of the patients, and then return and prepare the food for the families in luxurious residential districts.

We must not allow these plague spots to exist. If we are to do away with residual typhoid, and lead in that as Massachusetts has led in the elimination of water-borne typhoid, we must take up the question of personal cleanliness. We must educate the people to personal cleanliness, and so far as our city and state boards of health are concerned we must see to it that those powers which exist, and which to-day in the case of our city boards of health are ample to do what need be done, are exercised vigorously and forcibly.

THE PRESIDENT. It seems to me, gentlemen, that the water-works superintendents ought to go home from this meeting feeling pretty happy. Heretofore every time that there has been a typhoid fever epidemic it has always been said that the water has been to blame, and now we have found typhoid fever in pretty large quantities where the water has nothing whatever to do with it. It is now time for the boards of health, which have hitherto told the water-works superintendents to go ahead and do the work, to go ahead and do something themselves. So I think we all have had reason to feel very well satisfied with ourselves in view of what we have heard in this symposium here to-day. I should like to ask Professor Kinnicutt to say a few words.

PROF. LEONARD P. KINNICUTT.* Mr. President, I think this is a little bit rough on me. I am not at all in a pleasant mood. In

* Worcester Polytechnic Institute, Worcester, Mass.

order to get here I had to go without my lunch, so I am not in that happy frame of mind that I might have been if I had partaken of my lunch here with you. Then, again, in the mail this morning I received the following letter which I didn't open until I entered the train: "*Dear Sir*, — Please review the enclosed typewritten transcript of your remarks, made at the meeting of the Public Health Association, and return the corrected copy to me as soon as possible." I may say that I was called upon there unexpectedly, in the same way as the president has called upon me now, to say a few words regarding "Trade Wastes." I opened this copy, and the first sentence that met my eye was this: "In Worcester there is one very large concern, the American Iron and Steel Company, that use a very large amount of sulphuric acid in pickling their hams. [Laughter.] This iron sheet paper is thrown into the stream and causes great pollution." [Laughter.] I threw the copy aside, and made a solemn vow I would never speak again without being prepared. [Laughter.] I am afraid, however, like most of my good resolutions, it will only last for a short time. [Laughter.]

But, really, I have only a very few words to say to-day, and after what I am going to say I am afraid that you may not go home in quite the happy frame of mind your president expected you to. There is no question, as I think it has been very well shown in what has been said here to-day, that typhoid fever is not only a water-borne disease, but a contact disease. Professor Winslow, however, in his remarks suggested one question which I have been asking myself ever since I came into this room, and that is, Why is it that where you have well-cared-for and well-purified water supplies, the typhoid fever rate in Germany is only from 5 to 10 per 100 000, and in this country, as Professor Sedgwick has said, it is between 18 and 25 per 100 000? It cannot be claimed that the Germans are a more cleanly people than we are in this country. In the first place, the water-closet is nowhere nearly as common in Germany as it is here, and the privy is very much more common. Also, in the poorer quarters in the large cities like Berlin and Munich, there are just as bad conditions as are found in our tenement-house districts. They also have the fruit sold on the streets just as we have it sold here, and I imagine

that a great deal more fruit is bought on the streets at the little booths than is bought from peddlers in this country.

I think it is a question which we should ask ourselves, then, Why is it that we have in our cities here, which have a good water supply, a higher death-rate from typhoid fever than they do in Germany? Now, I think that one thing should be borne in mind regarding our water supplies. The water supplies of our chief cities in New England, as Professor Sedgwick has said, are generally good, pure water supplies. But let us go into the country; let us go into Vermont; let us go into New Hampshire. I have had occasion during the past two months to look over the returns from the State Board of Health of Vermont, and I have found that of the wells there which have been investigated during the past year, one-half contain polluted waters; and I mean by polluted waters, waters which receive sewage drainage. I think possibly that may account for a certain increase in our typhoid death-rate even in cities where we do have good sanitary water supplies. I am one of Professor Sedgwick's pupils, and I hate to make any statement in his presence, so I will merely ask the question: What would the effect be upon the typhoid fever death-rate in our cities if we could in any way obtain a perfect water supply all through the country?

MR. FREEMAN C. COFFIN.* Mr. President, it is very interesting for us to learn that typhoid fever which is not caused by a defective water supply is caused by low rents. That may be very pleasing to us, but I hope that the reporters will omit to mention the fact, because we all know that the landlords are an altruistic set of people and I am afraid that they would raise their rents immediately. (Laughter.)

THE PRESIDENT. Will Dr. Hollis say something?

DR. FREDERICK S. HOLLIS.† Mr. President and gentlemen, I came without preparation or thought of having anything to say, and must confine my remarks to tests which I have made from wells in different towns in Connecticut, particularly those used to some extent by the public, samples from a great many of which were received from the health authorities of the various towns.

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* Civil Engineer, Boston, Mass.
† Tufts Medical School, Boston, Mass.

Many of these were found to be highly polluted, as was shown by the presence of bacillus coli; and I have no doubt that many of these wells, the water from which is not infrequently used in preference to that of the public supply, are, as Mr. Weston has said of many springs, sources of infection.

I have felt that this branch of work, the study of samples taken at the discretion of the local health authorities from semi-public wells, is very important.

Of the seventy-two wells examined during two years, the majority of which were of this character and under suspicion, thirty-two gave positive tests for bacillus coli, seven gave doubtful results and thirty-three gave results that were negative.

The President. Mr. Locke, we should like to hear from you.

Mr. William W. Locke. I haven't a great deal to add, Mr. President, to what has already been said. While traveling up and down the Metropolitan watersheds I have occasionally found isolated cases of typhoid fever which probably came from polluted wells; in most cases that seems to be the indication. We do our best to prevent the spread of the disease to other individuals or localities, and I think the records show that not many cases of that kind come to Boston. In connection with a recent suit for damages, one of the commissioners made the statement that he had been told by a sanitary expert that typhoid fever came from other sources than from human beings, that is, that animals propagated the disease, and it was spread through animals. I should like to ask the question of the experts here to-day whether there has ever been a well authenticated case where typhoid has come through animals.

Professor Sedgwick. I never heard of any.

ELECTRIC PUMPING AT SCHENECTADY, N. Y.

BY G. S. HOOK, CIVIL ENGINEER, SCHENECTADY, N. Y.

[*Presented September 14, 1905.*]

Wherever cheap power is available, it would appear that an electrically driven municipal pumping plant should offer many advantages well worth considering, both by water-works superintendents and fire protection engineers. Nor can electric pumping now be considered merely experimental, for since October, 1904, the city of Schenectady, N. Y., has received its entire water supply by this method, and Buffalo, N. Y., has been using electric power for a like purpose. The letting of contracts for the electrical equipment of pumping stations for the New York high-pressure fire supply in both Manhattan and Brooklyn boroughs also indicates that the compactness, simplicity, and prompt service of the electric motor, when applied to emergency pumps of large capacity, is now being recognized by insurance engineers and underwriters.

As Schenectady has been the pioneer in the use of electric power for a high-pressure municipal water supply, a description of the plant now in continuous operation there should naturally find a place in the literature of this important subject.

The new electric pumping plant of the Schenectady Water Works is located at Rotterdam, N. Y., about three miles west of Schenectady, adjacent to the old plant, which is equipped with two vertical steam pumps of 6 000 000 gallons daily capacity each.

Plate I, Fig. 1, is an exterior view of the steam and electric pumping stations, and gives a good comparison of the sizes of the two plants. The small building at the left, solidly built of brick and steel, is the new electric station. Its rated capacity is 24 000 000 gallons in twenty-four hours, against a head of 110 pounds per square inch — twice the output of the old steam plant — and it occupies a very much smaller ground space.

The pumps are 18-inch two-stage vertical shaft turbine type.

built by Henry R. Worthington. They consist of an outer casing, inside which is located a set of fixed diffusion rings and vanes, and a rotating runner or "impeller." The water enters the top of the casing at the center of the impeller, and is thrown out through the diffusion vanes into the discharge chamber. The vanes are so curved as to transform the kinetic energy, imparted to the water by the pump, into static pressure with minimum loss. The pumps are installed in the 21-foot pit of the station, as shown in Plate I, Fig. 2, and Plate III, and draw the water through a 42-inch suction pipe from two circular wells 42 feet and 35 feet deep and 50 feet in diameter. These wells are near the electric pumping station building and are covered by a steel-reinforced concrete structure. They have 3-foot concrete walls and gravel bottoms, up through which the water filters. One of the wells is to be seen in the foreground of Plate I, Fig. 1.

The vertical shafts of the two main pumps extend to the station floor and are direct-coupled to the rotors of two 800 horse-power (rated), 550-volt, 40-cycle, three-phase General Electric squirrel-cage induction motors, installed on the station floor (Plate I, Fig. 2, and Plates II and III). The rated speed of the motors is 800 revolutions per minute, and their lubrication, a very important matter at such high speed, is effected by forcing oil, at a pressure of about 100 pounds, under the thrust bearing, which is arranged in the horizontal bearing shield on top of the motor. For supplying the oil, two vertical triplex Knowles oil pumps, each direct-driven by a geared 3 horse-power induction motor, are provided. Since the main pumps are located above the normal water level of the wells, a two-cylinder, 9-inch × 7-inch vacuum pump, direct driven by a 5 horse-power induction motor, is installed on the station floor and used to produce a vacuum in the suction pipe so as to draw the water to the pumps when starting up. A drainage pump of the Worthington one-stage vertical volute type is installed in the pit. Its vertical shaft extends like that of the main pumps to the station floor, and it is driven at 1 200 revolutions per minute by a direct connected, 5 horse-power, three-phase induction motor installed near the priming pump, as shown in Plate I, Fig. 2, and Plate III. All of the motors are supplied with 550-volt, 40-cycle, three-phase current, and have squirrel-cage rotors.

Fig. 1. Schenectady Water Works Pumping Stations, Rotterdam, N. Y.

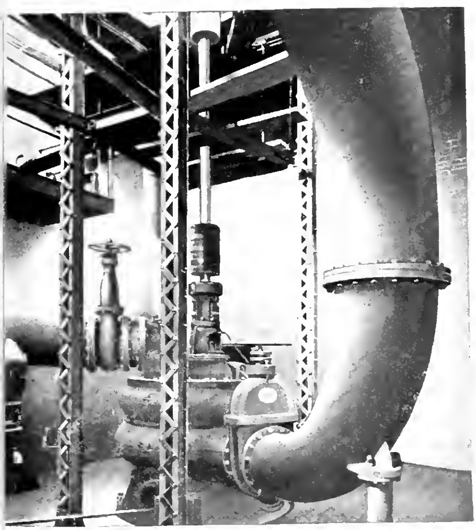


Fig. 2. One of the 12 000 000 Gallon Induction Motor Driven Pumps, Rotterdam Pumping Station.

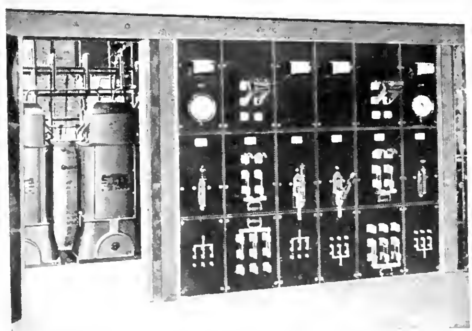
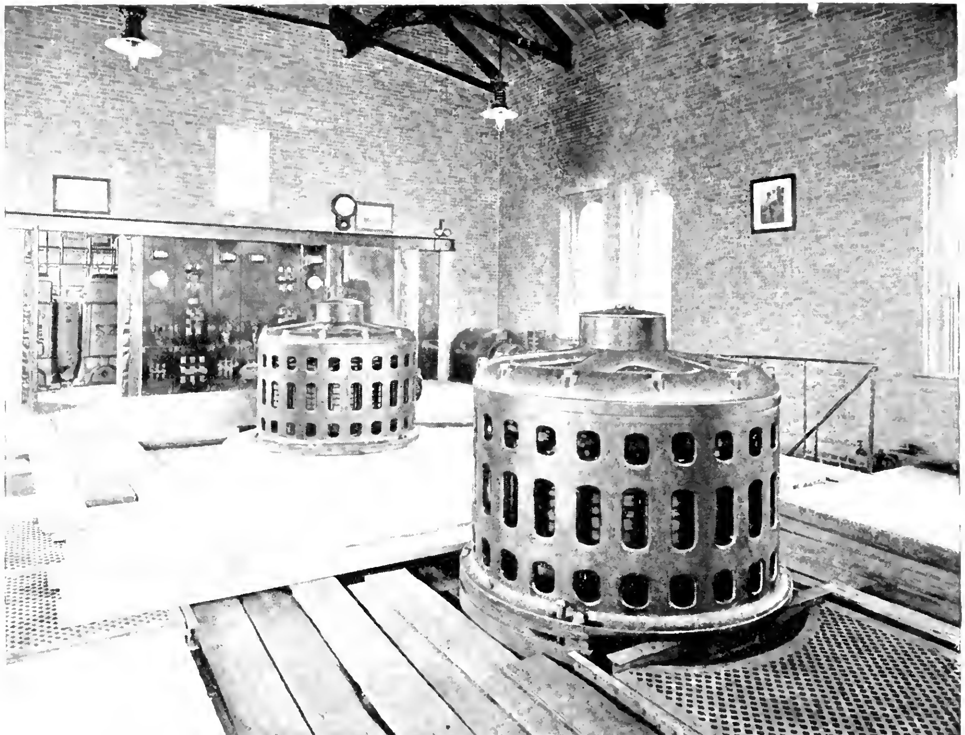
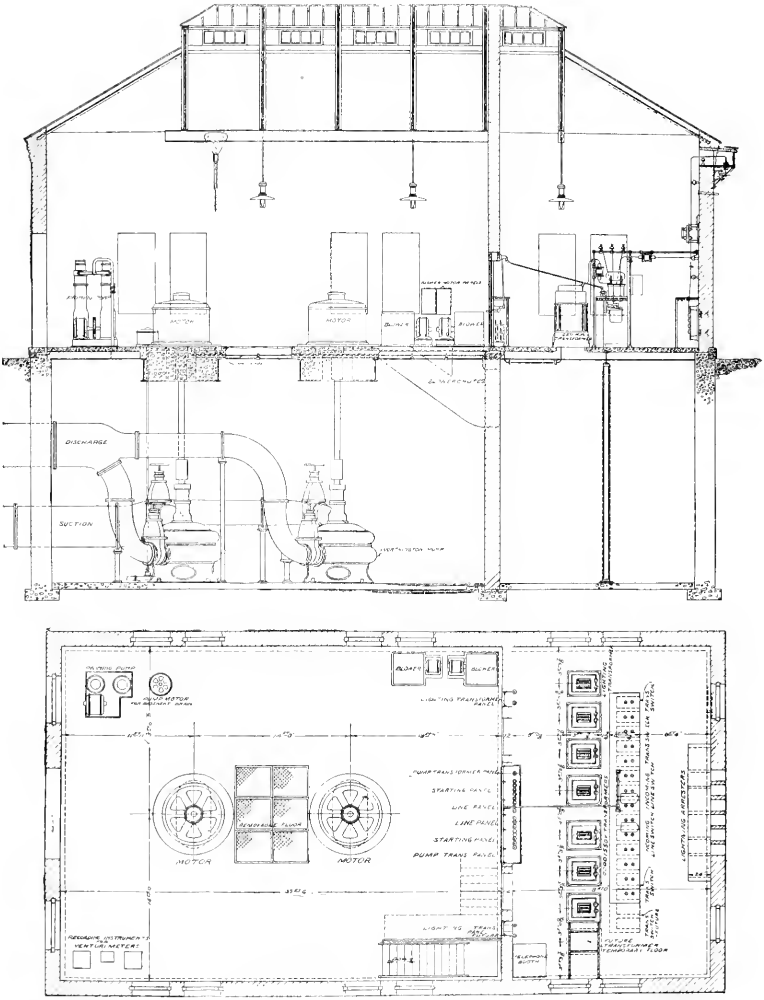


Fig. 3. Rotterdam Pumping Station Switchboard, Built into the Partition between the Motor and Transformer Rooms.



INTERIOR OF THE ROTTERDAM PUMPING STATION, SCHENECTADY WATER WORKS, SHOWING THE TWO 800 HORSE-POWER VERTICAL SHAFT INDUCTION MOTORS FOR OPERATING THE MAIN PUMPS.

PLATE III.



PLAN AND SECTION OF ELECTRIC PUMPING STATION AT ROTTERDAM, SCHENECTADY WATER WORKS.

Two separate and independent 10 000-volt transmission lines are provided, running from the Dock Street substation of the Schenectady Illuminating Company, which furnishes the city of Schenectady with power, and which receives its current from the water-power station in Mechanicsville and Spiers Falls. The lines are also connected to the power stations of the General Electric Works as a further source of power. The lines are controlled at both ends by General Electric automatic oil switches, and protected at both ends by General Electric lightning arresters. The oil switches are so adjusted that a heavy overload of the pump motors will trip the switches at the pumping station end of the line only, so that the pump service can be resumed immediately by closing these switches. On the other hand, a dangerous overload, or a short circuit on the line, will trip the generating station switches also, thus protecting line and apparatus against injury.

At the pumping station the high-tension current is stepped down to 550 volts by two banks of three 250-kilowatt single-phase air-blast transformers (Plate I, Fig. 3; and Plates II and III). The transformer secondaries are provided with taps, wired to double-throw switches, for starting the 800 horse-power main pump motors at quarter and half voltage in order to avoid the heavy rush of current that would be caused if the motors were started at full voltage. There is also installed a 150-kilowatt, 10 500/9 500–2 400/2 200 volt lighting transformer, which supplies current to the village and the railway station nearby. The necessary air blast is supplied by two independent induction-motor-driven blowers installed on the station floor.

A fireproof partition separates the roomy compartment containing the bus-bars and all of the high-tension apparatus — lightning arresters, disconnecting switches, oil switches, transformers, etc. — from the motor room, and the entrance from one to the other is closed by fireproof doors. Imbedded in and forming part of the partition is the switchboard, containing two incoming line panels, two high-tension transformer panels, and two low-tension main motor panels, equipped with the necessary ammeters, voltmeters, low-tension lever switches for controlling the main pump motors, and handles for the remote control of the high-tension oil switches which are installed in fireproof

brick cells. On these panels are also installed the lever switches controlling the auxiliary motors, and the vacuum and water-pressure gages. Plate 1, Fig. 3, gives a view of this switchboard, with the transformers, high-tension switches, bus-bars, etc., visible through the open door at the left.

The electrical layout is designed to coöperate with the use of the two independent supply lines in preventing any possibility of a total shutdown of the entire plant, upon the continuous operation of which depends the water supply of the city of Schenectady. Two sets of low-tension busses are provided, and the double-throw switches enable either of the two banks of transformers to be switched on to either one of the two sets of bus-bars. The main and auxiliary switches are also double-throw, to facilitate switching over from one bus to the other.

The turbine centrifugal pump is especially adapted to meet extraordinary demands for a large supply of water. For instance, in the case of a large fire, where a heavy demand for water is made beyond the nominal capacity of the pumps, and a reduction in pressure follows, the turbine centrifugal pump will, under these conditions, deliver a very largely increased amount of water when operating against the reduced pressure.

In the Rotterdam installation the pumps are designed to deliver at the rate of 12 000 000 gallons each per twenty-four hours, against a working pressure of 110 pounds. A further requirement is that with all the outlets from the pumps closed and the pumps and motors running at full rated speed, the pressure shall not exceed 120 pounds per square inch. This requirement is completely fulfilled by these centrifugal pumps, thereby avoiding all liability of the very serious accidents which have occurred to water mains supplied by reciprocating pumping engines and to these engines themselves, when, through either accident or design, the valves or distributing mains have been closed.

The electrically driven turbine pump requires less than half of the space needed for the most compact form of reciprocating steam pumping plant of equal capacity. A comparatively light and inexpensive foundation is required, as there is an entire absence of stresses due to reciprocating motions. The only moving part is the rotor-driven impeller, and there is comparatively little noise

or vibration. Little or no expenditure is required for upkeep and repairs, as the only wearing surfaces are the bearings. The attendance and depreciation are, therefore, nominal.

All of the electrical apparatus in this pumping station is of General Electric make. The station has now been in continuous satisfactory operation for nearly a year, and the adjoining steam station, formerly used, has been entirely shut down.

It may be added that the efficient response to several extraordinary demands made upon this system during large fires, when as many as 19 hose streams have been taken from consecutive hydrants, has proved to the insurance interests that these pumps can be speeded up to meet any emergency within the delivering capacity of the mains.

WILLIAM THOMPSON SEDGWICK: PRESIDENT NEW ENGLAND WATER WORKS ASSOCIATION.

BY M. N. BAKER, ASSOCIATE EDITOR, "ENGINEERING NEWS."

[*Reprinted* from "Engineering News" of January 11, 1906.*]

The New England Water Works Association did credit to itself, as well as to Prof. William T. Sedgwick, of the Massachusetts Institute of Technology, by electing the latter as its president on January 10. Professor Sedgwick has long been a stanch supporter of the association and has taken no small part in the development and application of knowledge of pure water supplies, how to get them and how to keep them. He has also contributed largely to other branches of sanitary science, and, as will appear later, has had important connections with municipal and state civil service reform. In view of all the foregoing facts we take pleasure in presenting herewith a biographical sketch and portrait † of this newly elected society president.

William Thompson Sedgwick was born in West Hartford, Conn., on December 29, 1855. He was the son of William and Ann (Thompson) Sedgwick, and a direct descendant of Robert Sedgwick, of Charlestown (Boston), Mass. The latter was born in Woburn, England, in 1611, arrived in Boston in 1636–7, died in Jamaica, W. I., in 1656, after having been sent from Boston by Oliver Cromwell as major-general to command the British forces in Jamaica.

The subject of this sketch prepared for college at the Hartford high school, and in 1877 graduated with the degree of Ph.B. in biology from the Sheffield Scientific School at Yale. After a year as a student of medicine, and a like period as instructor in physiological chemistry, at Yale, Mr. Sedgwick went to Johns Hopkins University. Here he was, successively, fellow, instructor, and associate in biology, from 1879 to 1883, receiving the degree of Ph.D. in 1881. In December, 1881, he was married to Mary Katrine Rice, of New Haven, Conn. In 1883, by invitation of

* With slight changes.

† See frontispiece. This portrait is from a later photograph than the one printed in *Engineering News*.

Gen. Francis A. Walker, he went to the Massachusetts Institute of Technology as assistant professor of biology, rising to associate professor in 1885, and to the full professorship in 1891, which he has held ever since. In 1902 he was made director of the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology.

To water-works men and municipal sanitarians Professor Sedgwick made himself widely known during the period from 1888 to 1896, by his services as biologist of the Massachusetts State Board of Health. In this capacity he took an important part in the studies of water and sewage purification at the Lawrence Experiment Station, collaborating with Hiram F. Mills, engineer member of the board, the late Thomas M. Drown, then chemist of the board, and F. P. Stearns, M. Am. Soc. C. E., then chief engineer to the board. It was under the guidance of such men as these, including, of course, Professor Sedgwick, that Messrs. Allen Hazen, George W. Fuller, H. W. Clark, E. O. Jordan, W. R. Copeland, and many other well-known water and sewage engineers, chemists, and bacteriologists had their early training and inspiration.

During his connection with the Massachusetts State Board of Health, Professor Sedgwick made a number of notable studies of water- and milk-borne epidemics of typhoid fever, accounts of which may be found in the annual reports of the board. Just before the Columbian Exposition, Professor Sedgwick published, in conjunction with Mr. Allen Hazen, an exhaustive historical and sanitary study of typhoid fever at Chicago, giving comparisons with New York, Boston, and other cities (see *Engineering News*, April 21, 1902). Later, Professor Sedgwick reported on water supply and typhoid fever at Burlington, Vt. (see JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, March, 1896), and at Pittsburg, Pa. (see "Report of Pittsburg Filtration Commission," 1899). He has contributed a number of papers to the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, one of the most valuable being an "end of the century" address, on "The Rise and Progress of Water Supply Sanitation in the Nineteenth Century,"* read in 1901 before the association which has now chosen him for its president.

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* Vol. 15, p. 315 (June, 1901).

A mere enumeration of the most important official positions held by Professor Sedgwick since 1896, many of which he is still filling, indicates his wide range of interests and public and semi-public services: curator, Lowell Institute, Boston, since 1897; chairman, pauper institutions trustees, city of Boston, 1897–99, and acting institutions registrar, 1899–1900; vice-president, Boston Society of Municipal Officers, 1899–1901; trustee, Simmons College, Boston, since 1899; chairman, American Society of Bacteriologists, 1899, and president, 1900; president, Boston Civil Service Reform Association, 1900, and Massachusetts Civil Service Reform Association, 1901; president, American Society of Naturalists, 1901; president, Board of Directors, Sharon (Mass.) Sanatorium for Consumptives, since 1902; member, Advisory Board Hygienic Laboratory, Public Health and Marine Hospital Service, since 1902; one of the principal experts, Chicago Drainage Canal case, 1903–4; member, Board of Trustees, Faulkner Hospital, Boston, since 1903; member, School Committee, Brookline, Mass., since 1904; vice-president, and chairman Section K (Physiology and Experimental Medicine), American Association for the Advancement of Science, 1904–5.

As a writer or public speaker on his chosen subjects Professor Sedgwick has few equals in clearness, force, grace of expression, and power of holding his readers or hearers. Besides his many official reports, and his addresses and papers before the New England Water Works Association and other organizations, he is the joint author with the distinguished Prof. E. B. Wilson, of Columbia University, of "General Biology" (*American Science Series*, first edition, 1886); assistant editor of the "Life and Letters of William Barton Rogers," founder and first president of the Massachusetts Institute of Technology (1896); and author of the "Principles of Sanitary Science and Public Health" (1902). In collaboration with Professor Hough, formerly his assistant professor, and now of Simmons College, he has in press a novel and original textbook for high schools and colleges, entitled "The Human Mechanism: Its Physiology and Hygiene, and the Sanitation of Its Surroundings."

This sketch would not do full justice to its subject if it failed to mention Professor Sedgwick's notable achievements as a teacher.

Of these it is only necessary to say here that to his high capacity for instruction he joins powers of inspiring his pupils with his own zeal for both conscientious routine work and for original research, and that his pupils are eagerly sought to fill positions demanding a combination of high scientific attainments, a willingness to work, and personal integrity; that is, he turns out men as well as scientists.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 13, 1905.

Mr. George Bowers, President, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, F. A. Barbour, G. W. Batchelder, J. F. Bigelow, J. W. Blackmer, George Bowers, E. C. Brooks, J. C. Chase, F. C. Coffin, M. F. Collins, W. R. Conard, F. H. Crandall, A. O. Doane, C. R. Felton, J. N. Ferguson, W. E. Foss, A. N. French, E. V. French, F. L. Fuller, T. C. Gleason, A. S. Glover, J. A. Gould, F. E. Hall, J. C. Hammond, Jr., V. C. Hastings, D. A. Heffernan, H. G. Holden, J. L. Howard, E. W. Kent, Willard Kent, J. W. Killam, F. C. Kimball, G. A. King, F. A. McInnes, D. E. Makepeace, W. E. Maybury, John Mayo, A. S. Merrill, H. A. Miller, F. L. Northrop, J. H. Perkins, Dwight Porter, W. W. Robertson, C. W. Sherman, Sidney Smith, G. H. Snell, J. T. Stevens, W. F. Sullivan, C. N. Taylor, L. A. Taylor, R. J. Thomas, W. H. Vaughn, C. K. Walker, Elbert Wheeler, J. C. Whitney, G. E. Wilde, O. J. Whitney, F. I. Winslow, G. E. Winslow, F. E. Winsor. — 61.

Associates.

Ashton Valve Co., by H. H. Ashton and C. W. Houghton; Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edw. F. Hughes; Coffin Valve Co., by H. L. Weston; Henry A. Desper; Hersey Mfg. Co., by J. A. Tilden, Albert S. Glover, W. A. Hersey; International Steam Pump Co., by Samuel Harrison; H. Mueller Mfg. Co., by George A. Caldwell; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by C. L. Brown and F. S. Bates; Ross Valve Co., by Wm. Ross; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop, A. S. Otis, W. F. Hogan, and L. P. Anderson; R. D. Wood & Co., by W. F. Woodburn. — 22.

Guests.

Arthur E. Blackmer, Supt. Water Works, Plymouth, Mass.; James E. Blake, Attleboro, Mass.; D. Potter, Braintree, Mass.; J. F. Gleason, Quincy, Mass., and Frank Grady, Comr., Medford, Mass. — 5.

[Names counted twice. — 3.]

The following were elected members: Edgar A. Weimer, Mayor, Lebanon, Pa.; Dr. Howard Nelson Kingsford, Professor of Pathology and Bacteriology, Dartmouth College, and New Hampshire State Bacteriologist, Hanover, N. H.; Irving T. Farnham, City Engineer, Newton, Mass.; W. F. McFarland, Superintendent Water Department, Washington, D. C.; Ira Gould Hoagland, connected with the Underwriters Bureau of New England, Auburndale, Mass.

There was no special business to come before the meeting, and the President called at once upon Mr. A. O. Doane, Division Engineer, Metropolitan Water and Sewerage Board, Boston, to read his paper on "Water Pressure Regulators." The subject was discussed by Messrs. William Ross, Frank L. Northrup, and George A. Caldwell, representing the manufacturers, and by Messrs. Edwin C. Brooks, Freeman C. Coffin, Charles N. Taylor, and F. I. Winslow.

Mr. Frank H. Crandall, chairman of the Committee on Private Fire Services, submitted a report in behalf of the committee, which was accepted and adopted by the association. The subject was discussed by Messrs. John C. Chase, Edward V. French, J. C. Hammond, Jr., Charles W. Sherman, Charles K. Walker, Frank C. Kimball, Horace G. Holden, Charles N. Taylor, R. C. P. Coggeshall, George H. Snell, and Frank L. Fuller. Mr. French, in the course of his remarks, made an appropriate allusion to the death of Mr. Edward Atkinson.

The subject announced for topical discussion was "Electrolysis." The discussion was opened by Mr. Edwin C. Brooks, of Cambridge. He was followed by Messrs. William E. Foss, John A. Gould, T. C. Gleason, R. C. P. Coggeshall, A. N. French, Edward V. French, and George E. Winslow.

On motion of Mr. Brooks, adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 10, 1906.

The President, Mr. George Bowers, in the chair.

The following members and guests were present:

MEMBERS.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, G. W. Batchelder, George Bowers, E. C. Brooks, G. A. P. Bucknam, James Burnie, E. J. Chadbourne, John C. Chase, W. F. Codd, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, G. K. Crandall, John Doyle, E. R. Dyer, G. E. Evans, F. L. Fuller, J. C. Gilbert, A. S. Glover, J. W. Griffin, R. A. Hale, J. O. Hall, J. C. Hammond, Jr., J. D. Hardy, H. G. Holden, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, Horace Kingman, C. F. Knowlton, J. W. Locke, M. O. Leighton, S. H. McKenzie, Hugh McLean, H. V. Macksey, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, A. S. Merrill, F. E. Merrill, H. A. Miller, T. W. Norcross, E. B. Phelps, W. W. Robertson, S. P. Senior, C. W. Sherman, Sidney Smith, G. H. Snell, G. A. Stacy, J. T. Stevens, W. F. Sullivan, W. M. Stone, L. A. Taylor, R. J. Thomas, W. H. Thomas, W. H. Vaughn, R. S. Weston, W. J. Wetherbee, J. C. Whitney, F. B. Wilkins, G. E. Winslow, E. T. Wiswall. — 69.

HONORARY MEMBERS.

William T. Sedgwick. — 1.

ASSOCIATES.

Chapman Valve Mfg. Co., by Edw. F. Hughes; Charles A. Claflin & Co., by Charles A. Claflin; Henry A. Desper; M. J. Drummond & Co., by Walter J. Drummond; The Fairbanks Co., by F. A. Leavitt; Fred C. Gifford; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, F. A. Smith; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by George A. Caldwell; Neptune Meter Co., by H. H. Kinsey; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Perrin, Seamans & Co., by C. E. Godfrey; The Platt Iron Works Co., by F. H. Hayes; Rensselaer Mfg. Co., by F. S. Bates and C. L. Brown; Ross Valve Co., by Wm. Ross; A. P. Smith Mfg. Co., by D. F. O'Brien and F. N. Whitcomb; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop, W. F. Hogan, Edw. P. King; R. D. Wood & Co., by W. F. Woodburn; Water Works Equipment Co., by W. H. Van Winkle. — 28.

GUESTS.

Patrick Gear, Asst. Supt., Holyoke, Mass.; F. P. Webster, Supt., Lakeport, N. H.; Eugene F. Garvey, Engr's Dept., Worcester, Mass.; A. R. McCollum, Supt., Whitman, Mass.; F. W. Holden, Norton, Mass.; J. F. Gleason, Supt., Quincy, Mass.; C. B. Breed, Boston, Mass.; Mr. Pratt, Portland, Conn.— 8.

[Names counted twice. — 3.]

The following named were elected to membership:

Active. — A. R. McCallum, Superintendent of Whitman Water Works, Whitman, Mass.; Eugene F. Garvey, Civil Engineer on Water Works Construction for the city of Worcester, Worcester, Mass.; Claude L. Howes, Engineer, Boston, Mass.

Associate. — The Anderson Coupling Company, Water Works Supplies, Portland, Conn.

President Bowers then delivered the following address:

President's Address.

Gentlemen of the New England Water Works Association. — Another year has passed away, and, as is our custom, we will review our year's work, or, as our M. I. T. friends across the street would say, take our annual examination.

Our first meeting of the year, January 11, was Ladies' Day, when we went on a personally conducted tour with our former president, Mr. Desmond FitzGerald, through the Philippines. By means of his fine lantern slides he showed us the present water works at Manila, and explained what it is intended to do there in the future. He also showed pictures of the people and their mode of living, closing a most interesting lecture with a series of beautiful views.

In February, we learned from Mr. Harvey D. Eaton what one man by persistent effort could accomplish in the way of securing municipal ownership of water supply, in the Kennebec water district. By combining several towns into a common water district, he has practically overthrown the old idea that town lines must always be recognized in constructing water works. This appears to be a movement in the right direction. Valuable papers were read by Mr. George C. Whipple and Dr. E. C. Levy on "The Kennebec Valley Typhoid Fever Epidemic of 1902 and 1903," showing conclusively that if people drink polluted water they must suffer the consequences. These papers were a very good preparation for what was to follow at the next meeting, which was held in March. At that time Prof. Erastus G. Smith explained the conditions existing along the Mississippi River, where that water is used as a means of supply, and the reckless manner in which the cities on its banks pollute the water. From our own experience in the East, we know the terrible effects that are sure to follow such inexcusable carelessness.

At the March meeting, also, a paper was read by Mr. William F. Sullivan on "Tests of Large Meters and Fire Service Devices," in which he showed that the large volume of water used in the

fire service could be measured without lessening its effectiveness. The insurance members disagreed with Mr. Sullivan, and promised to announce later the results of their own experiments on this subject; they did so in September, when Mr. E. V. French reported what they had done and stated that they were convinced that, by a suitable device, the water could be measured without detriment to the fire protection. This problem has been before the association for several years, and its solution should be a matter of general congratulation.

The invitation from the water commissioners of Attleboro, through Mr. George H. Snell, superintendent, to visit that place for our June outing and inspect the reinforced concrete standpipe then in process of construction, was accepted. On the arrival at that place of our party of 153, we found automobiles waiting to carry us to the standpipe, which is some distance from the center of the town. The work here was examined with a great deal of interest, but I shall not attempt to describe it, as Mr. Snell has promised to give us a paper on that subject later on. After stopping a short time to admire the magnificent view, we were carried to the pumping station, where we found a thoroughly up-to-date plant, of which the citizens of Attleboro may well feel proud. Entering the automobiles once more, we were taken back to the town at a rate that led us to judge that the speed limit law was a thing unknown to Attleboro chauffeurs. After enjoying a fine dinner, provided by our hosts, we were shown through several of the silver manufactories for which this place is noted. Thus ended one of our most enjoyable summer outings.

September 11, we left Boston for our Annual Convention, which was held this year in New York City. From first to last this convention was a grand success. The meetings were well attended, the papers, which I will not enumerate separately, interesting and instructive, and the discussions which followed, general and exhaustive. With 575 guests to attend to, the office of the Entertainment Committee was no sinecure. An automobile ride, a visit to the Hippodrome, a trip to Coney Island, a ride through the subway, and a day at the Croton Dam were among the attractions provided us. The thanks of this association are certainly

due the Committee on Arrangements and their sub-committees, whose efficient work made this in every respect the record-breaking convention of our society.

At the November meeting, introductory papers on the "Present Relative Responsibility of Public Water Supplies and Other Factors in the Causation of Typhoid Fever" were read by Dr. W. T. Sedgwick and Prof. C.-E. A. Winslow, explaining the various causes of typhoid epidemics. Then followed papers by Mr. E. E. Lochridge and Dr. George B. Magrath on the Springfield, Mass., typhoid epidemic, which was originally supposed to be caused by the water, but was readily traced by them to unsanitary conditions, showing negligence on the part of the board of health instead of the water board.

In December, Mr. A. O. Doane read a paper on "Water Pressure Regulators," which was fully discussed. The report of the Committee on Private Fire Services was read; this was followed by the discussion which this subject always brings out. Mr. Edwin C. Brooks exhibited a piece of cast-iron water pipe, several feet long, showing in a marked degree the effect of electrolysis, and explained the difference in the appearance of the pipe when taken from the ground and after several months' exposure to the atmosphere, and a general discussion on this subject followed.

That these meetings have been appreciated is shown by the large attendance throughout the year, and the increase of our membership from 604, January 1, 1905, to 645 at the present time.

We have sustained a great loss during the year in the death of five active members, Edward Atkinson, Henry A. Cook, Frank L. Fales, August Fels, and A. G. Pease, and one associate member, Edward Robinson.

Our headquarters at Tremont Temple have been enlarged by the addition of two rooms, so that we now have plenty of room for social intercourse before our meetings, and a separate room where the Executive Committee can hold its sessions undisturbed. We have just obtained a lease for a term of three years from the Boston Society of Civil Engineers at the same price paid before the additional rooms were secured. We feel sure that the members of this association will appreciate these convenient rooms and

also the excellent library, and we hope they will use them freely.

This association has always been well to the front in the discussion of matters within its sphere, its papers being the first brought out on many important subjects. It has been a director in many advanced ideas for the care and protection of water supplies, so that at the present time most of the water supplies in this vicinity are of good quality. Having secured good water, we should now exert ourselves to put a stop to the enormous waste of water which is going on around us. I was very glad to see that Mayor John F. Fitzgerald, in his inaugural address, recommended the use of water meters in Boston to remedy this evil, and I think his efforts in this direction should receive the support of our association. Fears are entertained that an additional water supply for Boston will be needed before long, and that some towns with their water supply will be seized, with the result that a new lake will make its appearance on the map. Such action should not be allowed while water is being wasted so needlessly, and should be guarded against by all the property owners of the state.

In conclusion, I should like to say a word about the JOURNAL, which, under the management of its energetic editor, is steadily increasing in value. The December number just issued, which contains a record of the copper sulphate discussion, will rank with any scientific magazine of the day.

All information in regard to membership and finance will be contained in the reports of the Secretary and Treasurer, which follow immediately.

I wish to thank you for the cordial manner in which you have supported me during the year, and to congratulate the association on the loyalty of its members.

REPORT OF SECRETARY.

The Secretary submitted the following report:

MEMBERSHIP.

The total membership of the association, January 1, 1905 was . .	604
The present membership is	645
A net increase during the year of	41

MEMBERS.

January 1, 1905.	Total members		538	
	Withdrawals:			
	Resigned	8		
	Died	5		
	Dropped	50	63	
			475	
	Initiations:			
	January	4		
	February	6		
	March	5		
	June	12		
	September	57		
	November	18		
	December	3	105	
	Reinstated		4	584

HONORARY MEMBERS.

January 1, 1905.	Honorary members		8	
January 1, 1906.	Honorary members			8

ASSOCIATES.

January 1, 1905.	Total associates		58	
	Withdrawals:			
	Resigned	2		
	Died	1		
	Dropped	5	8	
			50	
	Initiations:			
	February	1		
	September	2	3	53
January 1, 1906.	Total membership			645

Summary of Receipts and Disbursements of the New England Water Works Association for the Year 1905.

RECEIPTS.

Dues	$2 685.00
Advertisements	1 886.25
Initiations	410.00
Sundries	127.42
Subscriptions	126.50
Journals	103.05
	$5 338.22

DISBURSEMENTS.

Journal *	$2 072.04
Stationery	418.98
Assistant Secretary	420.00
Rent	400.00
Reprints and advance copies of papers	303.31
Sundry	302.96
Advertising Agent	300.50
Editor	300.00
Stenographer	240.75
Secretary	200.00
Membership list	127.83
Music	120.00
Badges	65.00
Furniture	34.00
Stereopticon	20.00
Library	15.00
Total	$5 370.37

Expenditures in excess of receipts $32.15

At the present time there is due the association:

For advertisements	$510.00
For reprints	6.50
For standard specifications	.40
For Journals	5.00
	$521.90

I know of no outstanding bills against the association.

Respectfully submitted,

WILLARD KENT, *Secretary.*

On motion of Mr. M. F. Collins the report of the Secretary was accepted and ordered to be placed on file.

Report of Treasurer.

The Treasurer submitted the following as his annual report:

* Including printing and illustrating only. — Ed.

Lewis M. Bancroft, Treasurer,
In account with the New England Water Works Association.

RECEIPTS.

1905.				
Jan. 5	Balance on hand		$2 869.15
Aug. 1	Dividend, Peoples' Savings Bank		54.67
Dec. 3	Dividend, Mechanics Savings Bank		38.27
Feb. 23	Rec'd of Willard Kent, Sec'y,	$1 620.00	
April 17	" " " "	345.01	
June 23	" " " "	516.05	
July 27	" " " "	272.75	
Oct. 9	" " " "	790.66	
Nov. 18	" " " "	821.65	
1906.			
Jan. 3	" " " "	972.10	5 338.22
			$8 300.31

EXPENDITURES.

Bills paid, as per itemized statement		$5 411.58
BALANCE ON HAND.		
Deposit Peoples' Savings Bank, Worcester	$1 506.05	
Deposit Mechanics Savings Bank, Reading	1 122.35	
Deposit First National Bank, Reading	260.33	
Total balance		2 888.73
		$8 300.31

LEWIS M. BANCROFT, *Treasurer.*

Reading, Mass., January 5, 1906.

DETAILED STATEMENT OF BILLS PAID.

1905.			
January	6	Miss J. M. Ham, ass't sec'y, December, 1904, salary,	$35.00
		Miss J. M. Ham, ass't sec'y, express, postage, etc.,	6.21
	21	William E. Whittaker, tracings	6.00
		Annie H. Virtue, music for January meeting . . .	60.00
		Thomas P. Taylor, stereopticon	10.00
		W. N. Hughes, book, dues 1905	6.00
		R. C. P. Coggeshall, expense auditing accounts . .	4.25
		William W. Robinson, expense auditing accounts .	4.50
	27	W. N. Hughes, envelopes and cards	12.75
		Hub Engraving Company, plates	5.80
February	4	Miss J. M. Ham, ass't sec'y, salary for January, 1905	35.00
		Miss J. M. Ham, ass't sec'y, cash paid for express, etc.	13.96
	21	L. M. Bancroft & Son, treasurer's bond	15.00
	28	Miss J. M. Ham, ass't sec'y, salary for February .	35.00
		Miss J. M. Ham, ass't sec'y, Committee on Meter Rates	6.50
		W. N. Hughes, envelopes and printing	22.25
		Hub Engraving Company, plates	13.28
March	2	Daggett's Orchestra, music, February meeting . .	15.00
	11	D. Gillies' Sons, stationery and printing	64.81
		Boston Society of Civil Engineers, rent to February 28	100.00
	31	Thomas P. Taylor, stereopticon	10.00
		Daggett's Orchestra, music, March meeting . . .	15.00
		Charles W. Sherman, salary and expenses to April 1,	91.00
		Hub Engraving Company, plates	19.48
April	10	Hub Engraving Company, plates	2.25
		W. N. Hughes, binding	5.00
		Bacon & Burpee, reporting January, February, and March meetings	40.00
		Miss J. M. Ham, ass't sec'y, salary for March . . .	35.00
May	3	Samuel Usher, printing March JOURNAL, reprints, and lists of members	599.73
		R. J. Thomas, advertising agent, commissions to April 1	74.50
		Miss J. M. Ham, ass't sec'y, salary for April . . .	35.00
		Willard Kent, secretary, salary to April 1	50.00
		Willard Kent, secretary, sundry expenses	53.90
June	1	D. Gillies' Sons, applications	7.75
		Miss J. M. Ham, ass't sec'y, salary for May	35.00
		Amount carried forward	$1 514.92

	Amount brought forward	$1 514.92
	Hub Engraving Company, plates	3.60
June 10	W. N. Hughes, envelopes and printing	55.00
	Charles W. Sherman, editor, salary and expenses to July 1	83.25
	Boston Society of Civil Engineers, rent to May 31 .	100.00
17	W. N. Hughes, envelopes and printing	15.58
26	Miss J. M. Ham, ass't sec'y, salary for June . . .	35.00
	R. J. Thomas, advertising agent, commissions to July 1	75.75
July 5	D. Gillies' Sons, printing	17.00
	Willard Kent, secretary, salary to July 1	50.00
	Willard Kent, secretary, sundry expenses	15.00
18	Samuel Usher, June JOURNAL and reprints	305.45
26	Miss J. M. Ham, ass't sec'y, salary for July . . .	35.00
August 14	W. N. Hughes, printing	3.50
	S. E. Tinkham, cash paid for cleaning books . . .	4.00
25	Hub Engraving Company, plates	14.80
30	Miss J. M. Ham, ass't sec'y, salary for August . .	35.00
	Miss J. M. Ham, ass't sec'y, sundry expense items,	37.84
September 6	W. N. Hughes, printing	5.00
18	American Society of Civil Engineers, binding . . .	6.00
	Charles .W. Sherman, editor, salary to October 1,	75.00
	Charles W. Sherman, editor, sundry expenses . .	7.65
	Samuel Usher, reprints	58.81
	Hub Engraving Company, plates	95.19
30	Whitehead & Hoag Company, badges	65.00
	The Globe-Wernicke Company, bookcases	34.00
	William E .Whittaker, tracings	3.00
October 3	Miss J. M. Ham, ass't sec'y, salary for September .	35.00
	Miss J. M. Ham, ass't sec'y, sundry expenses . . .	74.00
	Willard Kent, secretary, salary to October 1 . .	50.00
	Willard Kent, secretary, sundry expenses	10.00
	Bacon & Burpee, reporting New York Convention	141.50
10	D. Gillies' Sons, printing	52.85
	Boston Society of Civil Engineers, rent to August 31,	100.00
17	Hub Engraving Company, plates	37.01
	W. N. Hughes, printing	23.00
31	W. N. Hughes, printing	5.00
	Miss J. M. Ham, ass't sec'y, salary for October . .	35.00
November 3	Hub Engraving Company, plates	20.37
7	W. N. Hughes, printing	12.00
16	Hub Engraving Company, plates	4.60
	Amount carried forward	$3 410.67

	Amount brought forward	$3 410.67
	D. Gillies' Sons, printing	16.50
November 22	R. J. Thomas, advertising agent, commissions to November 1	76.50
December 5	Samuel Usher, September JOURNAL and reprints	515.30
	Miss J. M. Ham, ass't sec'y, salary for November	35.00
	W. N. Hughes, printing	2.00
15	Hub Engraving Company, plates	10.02
	Miss J. M. Ham, ass't sec'y, salary for December	35.00
	Miss J. M. Ham, ass't sec'y, Committee on Meter Rates	3.50
	Miss J. M. Ham, ass't sec'y, sundry expenses	21.38
	D. Gillies' Sons, printing	26.95
	Charles W. Sherman, editor, salary to December 31,	75.00
	Charles W. Sherman, editor, sundry expenses	10.65
18	W. N. Hughes, printing	7.75
	Willard Kent, secretary, salary to December 31	50.00
	Willard Kent, secretary, sundry expenses	74.40
23	Boston Society of Civil Engineers, rent to November 30	100.00
26	Samuel Usher, reprints	69.50
	Bacon & Burpee, reporting November and December meetings	59.25
	Frank E. Merrill, expenses account September convention	13.47
30	W. N. Hughes, dues book	6.00
	R. J. Thomas, advertising agent, commissions to December 3	73.75
	Samuel Usher, December JOURNAL	688.99
		$5 411.58

On motion of Mr. Tighe the report of the Treasurer was accepted and ordered placed on file.

Report of Editor.

The Editor submitted the following report:

January 10, 1906.

To the New England Water Works Association, — The following is my report as Editor of the Journal for the year 1905.

The accompanying tables show in detail the amount of material in the Journal, the receipts and expenditures, and a comparison with the five preceding volumes.

TABLE No. 1.

Statement of Material in Volume XIX, Journal of the New England Water Works Association, 1905.

Number.	Date of Issue.	Papers.	Proceedings.	Total Text.	Index, etc.	Advertisements.	Covers and Contents.	Inset Plates.	Total.	Cuts.
		Number of Pages of								
1	March	113	33	146	—	30	4	16	196	16
2	June	85	9	94	—	31	4	1	130	7
3	September	120	24	144	—	32	4	20	200	4
4	December	198	5	203	8	34	4	12	258	3
	Total	516	71	587	8	124	16	49	784	30

TABLE No. 2.

Receipts and Expenditures on Account of Volume XIX, Journal of the New England Water Works Association, 1905.

Receipts.		Expenditures.	
From advertisements	$1 886.25	For printing Journal	$1 836.64
From sale of Journals	103.05	For preparing illustrations	235.40
From sale of reprints	77.90	For editor's salary	300.00
From subscriptions	126.50	For editor's incidentals	50.05
	$2 193.70	For advertising agent's commissions	300.50
		For reporting	240.75
Net cost of Journal	$1 072.95	For reprints and advance copies	303.31
	$3 266.65	Gross cost of Journal	$3 266.65

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV, XV, XVI, XVII, XVIII, AND XIX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

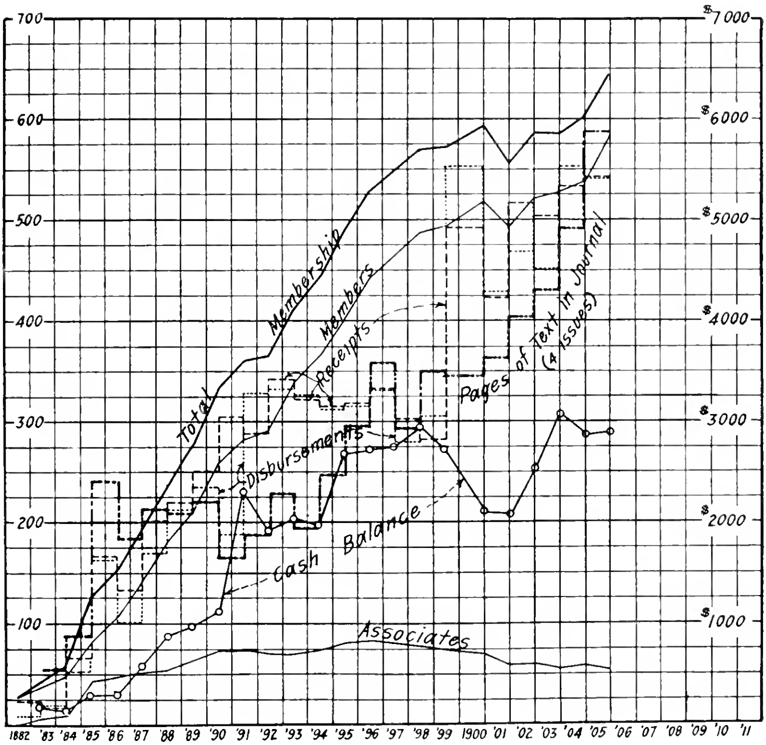
	VOL. XIV. 1899–1900.	4 NUMBERS OF VOL. XV. 1900–1901.	VOL. XVI. 1902.	VOL. XVII. 1903.	VOL. XVIII. 1904.	VOL. XIX. 1905.
Edition (copies)	1 100	1 200	1 200	1 200	900	900
Average membership	583	586	571	587	596	625
Pages of text	345	363	403	430	491	587
Pages of text per 1 000 members	600	618	707	733	824	939
Total pages, all kinds	485	536	584	619	794 *	784
Total pages per 1 000 members	832	913	1 020	1 051	1 332	1 254
GROSS COST:						
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65
Per page	4.03	4.10	4.18	4.38	3.69	4.17
Per member	3.35	3.75	4.27	4.61	4.91	5.23
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18	6.67
Per member per 1 000 pp. text	9.71	10.31	10.60	10.72	10.00	8.91
NET COST:						
Total	$347.55	$332.90	$622.89	$770.62	$648.11	$1 072.95
Per page	.72	.62	1.07	1.25	.82	1.37
Per member	.60	.57	1.09	1.31	1.09	1.72
Per member per 1 000 pages	1.23	1.06	1.87	2.12	1.30	2.20
Per member per 1 000 pp. text	1.73	1.57	2.71	3.05	2.22	2.93

* Including General Index.

I submit also a diagram showing the principal statistics of the Association from its formation to the present time.

NEW ENGLAND WATER WORKS ASSOCIATION

PRINCIPAL STATISTICS



The December, 1905, issue contained 28.08 pages of paid advertisements, which, if maintained throughout a year, would mean an annual income from this source of $1 985.00. A year ago the figures were 27.92 pages and $1 935.00, showing a slight increase during the year.

The unusual size of the present volume of the JOURNAL is worthy of note. This is largely due to the volume of the papers presented at the New York Convention, and is a testimonial principally to the activity of the local committee on program, of which Mr. George W. Fuller was chairman. As regards

quality, the papers speak for themselves. There certainly has been no reduction in the average quality of the papers published during the year.

The total cost of illustrations in the JOURNAL for the year has been $428.60, or 13.4 per cent. of the gross cost of the JOURNAL. This includes, in some cases, preparation of drawings, and in all cases making cuts and printing the illustrations. For the preceding volume the illustrations cost $300.83, which was 10.3 per cent. of the gross cost of the volume. The increase during the present year has been largely due to the cost of making and printing cuts to illustrate one or two papers, which papers, however, were of special interest and value and with which the illustrations were indispensable.

The usual fifty reprints of papers have been furnished to authors without charge; advance copies of a few of the papers presented have also been printed, which has made the item for reprints and advance copies considerably greater than usual. It is to be hoped that it may be possible in the near future to print all, or at least the greater part, of the papers to be presented before the association in advance, in order to allow more time for discussion and to make it possible to prepare discussions in advance. Up to the present, however, it has not been possible to secure many of the papers before the time of presentation. The net cost to the association of the reprints and advance copies has been $9.80 for each of the twenty-three papers published during the year.

The present circulation of the JOURNAL is:

Members (all grades)	645
Subscribers	44
Exchanges	16
	705

During the year pipe specifications have been sold to the amount of $28.70. A year ago we had a net gain of $28 from this source, so that at the present time we have received $56.70 more than the expense of printing these specifications. The association still has on hand a fair supply of the specifications.

I know of no outstanding bills against the association on account of the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

On motion of Mr. Chase the report was accepted and ordered placed on file.

REPORT OF THE FINANCE COMMITTEE.

Mr. W. W. Robertson, chairman, submitted the following as the report of Finance Committee.

BOSTON, MASS., January 6, 1906.

To the Members of the New England Water Works Association, — We, the undersigned members of the Finance Committee of this association for the past year, met this day at the headquarters of this association at Tremont Temple in this city, and proceeded as follows:

We first examined the Secretary's cash book, verified the additions, and found the total receipts as stated therein to be correct and to the amount of \$5 338.22, which amount the Secretary has transmitted to the Treasurer, and holds the receipt of the latter therefor. In the Secretary's report the amount uncollected from advertisements is seemingly large. It, however, is due to the fact that bills for same could not be issued until the December issue of the JOURNAL had been delivered. Sufficient time has not since elapsed to make the collection of this account.

An examination of the Treasurer's account shows that it agrees with that of the Secretary in the amount received, viz., \$5 338.22. We have checked every item in his entries of disbursements, amounting to \$5 411.58, and find each item properly approved and secured by vouchers. We have checked the Treasurer's statement of balance on hand January 6, 1906, \$2 888.73, by examining his bank account, and find the same to be correct.

We, therefore, as the result of this examination vouch for the accuracy of statements contained in the reports of the Secretary and Treasurer, which are submitted to you this day.

Your committee feels that the association is to be congratulated in having its financial affairs administered by such competent officials as are now in charge of same. The books show a large amount of detail, which is rapidly increasing in bulk each year. By far the larger portion of this increase in work falls upon our present efficient Assistant Secretary, Miss J. M. Ham, whose books we found in an exceedingly creditable and neat condition. For some time Miss Ham has been receiving a salary of \$35 per month. We think it only just that we should recognize the fact of her largely increased duties, due to the growth of the association. We therefore earnestly recommend that from this date onward Miss Ham's salary be increased to \$45 per month.

Respectfully submitted,

W. W. ROBERTSON,
R. C. P. COGGESHALL,
HARRY L. THOMAS,
Finance Committee.

On motion of Mr. R. J. Thomas the report of the committee was accepted and that portion of it referring to an increase of salary of the Assistant Secretary was referred to the Executive Committee.

Election of Officers.

(REPORT OF TELLERS OF ELECTION.)

Boston, Mass., January 10, 1906.

Mr. President, — The tellers appointed to canvass the ballots for the election of officers of the New England Water Works Association, for the year 1906, beg leave to report as follows:

Whole number of votes cast, 214.

For President.

*William T. Sedgwick, Boston, Mass.	214

For Vice-Presidents.

*J. Waldo Smith, New York, N. Y.	211
*Cyrus M. Lunt, Lewiston, Me.	209
*Frank A. Andrews, Nashua, N. H.	212
*John C. Chase, Derry, N. H.	210
*Frederick W. Gow, Medford, Mass.	212
*Joseph M. Birmingham, Hartford, Conn.	210
George H. Snell, Attleboro, Mass.	1
George A. King, Taunton, Mass.	1

For Secretary.

*Willard Kent, Narragansett Pier, R. I.	212
†J. M. Ham	1

For Treasurer.

*Lewis M. Bancroft, Reading, Mass.	211

For Editor.

*Charles W. Sherman, Boston, Mass.	212

For Advertising Agent.

*Robert J. Thomas, Lowell, Mass.	212

For Additional Members of Executive Committee.

*Frank E. Merrill, Somerville, Mass.	212
*George A. Stacy, Marlboro, Mass.	213
*James L. Tighe, Holyoke, Mass.	212

For Finance Committee, Three.

*Harry L. Thomas, Hingham, Mass.	213
*William E. Mayberry, Braintree, Mass.	213
*Arthur D. Marble, Lawrence, Mass.	214

Respectfully submitted,

WILLIAM F. SULLIVAN,
GEORGE A. KING,
Tellers.

* Elected. † Ineligible.

The President announced the election of the various officers as shown by the return of the tellers and then presented to the Association as its next president, "a man you all know and whom you all love, a man who has done as much for the association as any other member, Professor Sedgwick." [Applause.] Professor Sedgwick responded as follows:

Mr. President and Fellow Members, — When, a little over a year ago, you were kind enough to elect me an honorary member of this association, it seemed to me that you had done all and more than you ought to have done for me. I think I have never had a chance to express my thanks, as I now do, for that distinguished honor at your hands. But when in addition you have chosen me as your President for the ensuing year, you have indeed placed me under still greater obligation.

I should be a very conceited person if I supposed that in doing this you were conferring the distinction upon me alone, for I know it is rather upon the institution with which I am connected, and have been for many years, and upon my associates, former students, and friends who have been working along the same lines that I as a scientific man have been pursuing. And in that spirit, and as a token of your confidence, I have great pleasure in accepting, as I now do, the high honor which, in another form, you have for the second time conferred upon me.

I believe in this association. I have been with you here for a good many years, and I believe in the work that you are doing. A man who is a water-works superintendent or a water-works expert cannot be altogether a fool, and when his friends and his peers choose him for a place like this, it means a great deal. We have all worked together for a common end, the improvement of one of the great public services of the day; and the growth of the association, together with its reputation, which has grown with its membership, is a sufficient guarantee of the place which it now holds in American professional life. This might well be called an association of water-works engineers, but it has the more modest title of Water Works Association; and while limited in name to New England, it reaches in fact, as you know, all over the country.

It is one of the delightful things of our day that bodies of trained

men are getting together and correcting that over-specialization which is so characteristic of our times, by organization, bringing together men of kindred tastes and kindred pursuits. Our constitution states that this association is formed for "the advancement of knowledge relating to water works and water supply, and the encouragement of social intercourse among water-works men." We could not possibly have a better charter — improvement of our knowledge and improvement of our acquaintance, one with another. Let us see to it during the coming year, as we have seen to it during the years that have gone, that while adding to our knowledge we are also adding to our good fellowship. Let us look out particularly for the man who is off in some little place, facing problems which are quite as difficult for him as those which confront men in charge of bigger works, and let us also see to it that the good fellowship element is looked after in his case, which is often harder to manage than the purely professional problem. In view of all the splendid work which has been done by the association in the past, in view of the able administrations under which the association has grown large and strong, let us see if in this year which is to come we may not do even better work than ever before, — better for our science, better for good fellowship.

At our meeting next month, as you know, we are to have the ladies with us, and the committee having charge of the arrangements for Ladies' Day proposes, if its plans can be carried out, to furnish an unusually attractive program. I am happy to say that Mrs. Sedgwick will be here with me, and for half an hour or so before we sit down to dinner we will have a little social gathering and I hope you will all bring your wives or sweethearts or daughters, for after dinner we expect to have something which will be of interest to all. I trust there will be a large attendance and that it will be a banner day among all our ladies' days.

Now I am not going to talk any longer at present. You will have to bear with me for a whole year, and therefore I will cut my remarks short on this occasion, although I will not promise always to do as well in this respect. [Applause.]

The paper of the afternoon was on "Water-Works Construction of the United States Reclamation Service," by Mr. M. O.

Leighton, hydrographer in charge, Division of Hydro-Economics. It was illustrated by stereopticon views. At the close of his address Mr. Leighton answered questions asked by Messrs. Charles W. Sherman, Frank L. Fuller, John C. Whitney, and Sidney Smith.

Just before the meeting adjourned, Mr. R. C. P. Coggeshall said:

"There is one thing I want to bring up at this time. I was very much impressed by our President's modest résumé of the past year's work. I know something of what the administration has had in hand in carrying out that work, and I know how much the success of it has been due to our President. I think it is a good plan to recognize such service as he has given us in some formal way, and I, therefore, am going to make this motion, which I shall ask the Secretary to put, that the thanks of the association be given to George Bowers, the retiring president, for the excellent service which he has rendered us during the past year." [Loud applause.]

The motion was put by the Secretary and adopted by a rising vote.

PRESIDENT BOWERS. I thank you very much, gentlemen, for this expression of your appreciation and good-will.

February Meeting (Ladies' Day).

Hotel Brunswick,
Boston, February 14, 1906.

Prof. Wm. T. Sedgwick, President, in the chair.

The following members and guests were in attendance:

Members.

S. A. Agnew, F. E. Appleton, C. H. Baldwin, G. W. Batchelder, J. E. Beals, George Bowers, Fred. Brooks, James Burnie, F. H. Carter, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, J. H. Cook, M. J. Doyle, A. O. Doane, I. T. Farnham, J. H. Flynn, J. C. Gilbert, A. S. Glover, C. A. Hague, L. M. Hastings, G. W. Hawkes, H. G. Holden, J. L. Howard, H. R. Johnson, E. W. Kent, Willard Kent, G. A. King, Hugh McLean, H. V. Macksey, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, C. E. Peirce, T. A. Peirce, E. B. Phelps, Dwight Porter, W. H. Richards, C. W. Sherman, G. A. Stacy, C. N. Taylor, R. J. Thomas, D. N. Tower, W. H. Vaughn, R. S. Weston, J. C. Whitney, G. E. Winslow, F. E. Winsor, and E. T. Wiswall. — 52.

Honorary Member.

W. T. Sedgwick. — 1.

Associates.

Harold L. Bond & Co., by Harold L. Bond; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Coffin Valve Company, by H. L. Weston; Henry A. Desper; Fred C. Gifford; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, and Wm. C. Sherwood; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates; Ross Valve Company, by Wm. Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by S. D. Higley; Union Water Meter Company, by F. L. Northrop and W. F. Hogan; United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; Waldo Brothers, by E. W. Clark; R. D. Wood & Co., by W. F. Woodburn; Water Works Equipment Company, by W. H. Van Winkle. — 28.

GUESTS.

Mrs. Charles N. Taylor, Mrs. W. H. Vaughn, Wellesley Hills, Mass.; Miss Helen Willson, Mrs. Arthur I. Nash, Mrs. E. D. Phelps, Mrs. J. L. Howard, Mrs. Frank E. Winsor, Mrs. H. A. Miller, Mrs. A. O. Doane, Mrs. J. H. Flynn, Mrs. Frank C. Kimball, Miss Florence C. Kimball, Mrs. Samuel Harrison, Mr. Scribner, Mr. George E. Russell, Mr. Shepard, Boston, Mass.; Miss Alice S. Corner, P. J. B. Sullivan, R. Connor, Holyoke, Mass.; Mr. and Mrs. J. F. Gleason, Quincy, Mass.; Mrs. I. T. Farnham, West Newton, Mass.; Mrs. C. E. Peirce, East Providence, R. I.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. George A. Stacy, Marlboro, Mass.; Mrs. A. B. Arey, Miss Edith Arey, South Boston, Mass.; Mrs. F. H. Hayes, Mrs. E. C. Brooks, Cambridge, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. George Bowers, Mrs. F. E. Appleton, R. R. Thomas, Mrs. C. S. Proctor, Lowell, Mass.; Mrs. Wm. T. Sedgwick, Wm. E. Mott, Brookline, Mass.; J. F. James, Lawrence, Mass.; Mr. and Mrs. H. W. Sears, Mr. and Mrs. Walter L. Beals, Middleboro, Mass.; Mrs. John C. Chase, Derry, N. H.; Mrs. H. G. Holden, Nashua, N. H.; Mrs. John H. Cook, Paterson, N. J.; Mrs. Charles W. Sherman, Belmont, Mass.; Miss Lillian Leavitt, Somerville, Mass.; Miss Helen R. Coggeshall, New Bedford, Mass.; Mrs. W. H. Richards, Miss Helen M. Richards, H. S. Richards, New London, Conn.; Mrs. Thomas A. Peirce, East Greenwich, R. I. — 51.

The following applicants, who were recommended by the Executive Committee, were elected to membership:

C. H. Turner, Treas. St. Johnsbury Aq. Co., St. Johnsbury, Vt.; W. Donaldson, Knoxville Water Co., Knoxville, Ky.; Frank E. Pressey, Hydgr., U. S. G. S., Bangor, Me.; A. B. Hill, Cons. Eng., New Haven, Conn.; Herbert P. Linnell, Res. Eng., Water Works, Colon, Cristobal, Canal Zone; H. J. Glendenning, C. E., Portland, Me.; C. Robert Adams, U. S. G. S., Boston; Edward R. Mack, Water Department, Wilmington, Del.; Horace H. Chase, C. E., Brockton, Mass.; Peter A. Monteverde, Superintendent, Trafford City, Trafford County, Pa.; Lewis E. Smith, C. E., Pasadena, Cal.; Edmund M. Blake, C. E., Boston.

President Sedgwick welcomed the ladies and called attention to the happy coincidence of our Ladies' Day falling upon St. Valentine's Day, after which he introduced Arthur I. Nash, Esq., of Boston, who gave a very interesting address, illustrated by stereopticon, on the beaver, under the title, "Primitive Water Works and Water Workers of New England."

Adjourned.

EXECUTIVE COMMITTEE.

December 13, 1905.

Present: President George Bowers, and George A. Stacy, Robert J. Thomas, L. M. Bancroft, Charles W. Sherman, and Willard Kent.

The Secretary read applications for membership from the following persons:

Irving T. Farnham, Howard N. Kingsford, Ira G. Hoagland, Edgar A. Weimer, and W. A. McFarland; and it was voted to recommend the applicants for election.

A letter was read from Mr. Luther C. Wright, superintendent, Water Works, Northampton, Mass., a former member of the association in good standing, signifying his desire to again become a member. By unanimous vote of the Executive Committee, Mr. Wright was reinstated to membership in the association.

On motion of Mr. Sherman it was voted: That surplus numbers of the Journal of the Association, in excess of five copies of each issue, be disposed of at the rate of one dollar each.

Voted: That the President be and hereby is authorized to appoint a special committee to make arrangements for Ladies' Day on the date of the February meeting.

Adjourned.

Attest: Willard Kent, *Secretary.*

Boston, January 10, 1906.

Present: President George Bowers, and Frank E. Merrill, James L. Tighe, Charles W. Sherman, Frederick W. Gow, L. M. Bancroft, Robert J. Thomas, and Willard Kent.

Applications were received from A. R. McCallum, Whitman, Mass.; Eugene F. Garvey, Worcester, Mass., and Claude L. Howes, M. E., Boston, Mass., for active membership, and from the Anderson Coupling Company, of Portland, Conn., for

associate membership, and they were by vote unanimously recommended therefor.

The salary of the Assistant Secretary, on recommendation of the Finance Committee, was by vote increased to forty-five dollars ($45) per month.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

FEBRUARY 14, 1906.

Present: John C. Chase, chairman; Frank E. Merrill, George A. Stacy, James L. Tighe, Willard Kent, Charles W. Sherman, and Robert J. Thomas.

Applications were received from C. H. Turner, St. Johnsbury, Vt.; W. Donaldson, Knoxville, Tenn.; Frank E. Pressey, Bangor, Me.; Albert B. Hill, New Haven, Conn.; Edward R. Mack, Wilmington, Del.; Horace H. Chase, Brockton, Mass.; Peter A. Monteverde, Trafford City, Pa.; Lewis E. Smith, Pasadena, Cal.; Herbert P. Linnell, Cristobal, Canal Zone; H. J. Glendenning, Portland, Me.; C. Robert Adams, Boston, Mass.; and Edmund M. Blake, Boston, Mass.; and they were by vote recommended for membership in the association.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Edward Atkinson, president of the Boston Manufacturers' Mutual Fire Insurance Company, and well known as an economist and statistician, as well as perhaps the leading "anti-imperialist" of the country, died suddenly on December 11, 1905, as the result of an attack of acute indigestion, with which he was seized while driving from his home to his office that morning.

Mr. Atkinson was born in Brookline, Mass., on February 10, 1827, and was educated in private schools. His business training began in 1842 in a commission house; in 1848 he became identified with various manufacturing corporations, which he served as clerk or treasurer until 1877. He had been president of the Boston Manufacturers' Mutual Fire Insurance Company for nearly forty years. In this position he was the prime mover in establishing the inspection department of the Associated Factory Mutual Insurance Companies, which has done so much to advance, not only methods of construction, but our knowledge of principles and our practice in hydraulic engineering.

For many years he had been a vigorous and fearless writer on a wide range of subjects. He was a member of many societies, and had received many honors, among them the honorary degrees of LL.D. and Ph.D. He was one of the founders and for several years a member of the corporation of the Massachusetts Institute of Technology. He contributed two papers to this association on bog fuel, and frequently took part in the discussions.

Mr. Atkinson became a member of the New England Water Works Association on November 9, 1904.

BOOK NOTICES.

PRACTICAL CEMENT TESTING. By W. Purves Taylor, M.S., C.E., Engineer in charge, Philadelphia Municipal Testing Laboratory. New York: The Myron C. Clark Publishing Company, 13-21 Park Row. 1906. Pp. 315. 6 x 9 inches. Price, $3.00 net.

This book is, perhaps, the most complete work ever published on the subject of cement testing, and although from the number of pages it might be thought voluminous, it is concise and admirably arranged. It has been prepared with a view to its use by the novice in testing, and the matter is so presented as to be readily understood by him; at the same time it will doubtless prove of much value as a book of ready reference for the expert.

The first three chapters are of an introductory character, and deal briefly with the classification, constitution, and manufacture of cements. The body of the book, comprising Chapters 4 to 12, deals very fully with the usual or routine tests of cement and discusses the methods of making them and the interpretation of results. The remainder of the book is devoted to special tests, chemical analyses, methods of operating a laboratory, and numerous specifications. Mr. Taylor's wide experience in charge of the Philadelphia municipal laboratory is abundant proof of his qualifications for preparing such a book.

There are numerous illustrations, diagrams, and tables scattered through the book, which is concluded by a good index.

HANDBOOK OF COST DATA FOR CONTRACTORS AND ENGINEERS. A Reference Book giving Methods of Construction and Actual Costs of Materials and Labor on Numerous Engineering Works. By Halbert P. Gillette, Consulting Engineer, Member American Society Civil Engineers, Member American Institute Mechanical Engineers, late Associate Editor *Engineering News*. New York: Myron C. Clark, 13–21 Park Row. 1905. Pp. 610. 4 x 6½ inches. Price, $4.00 net.

This book can be highly commended to all having to do with construction work of any kind. Detailed records of cost of construction are comparatively seldom kept, and the average water-works superintendent, for instance, while he may know fairly well the total cost per foot of laying water pipes, has but a very hazy idea of the different items which go to make up that cost, and therefore can only guess at the effect of changes in conditions or of prices of certain supplies.

In the opening sentences the author says: "There are two principal objects in keeping itemized records of cost: (1) To enable the contractor or engineer to determine what will be fair unit prices for similar work in the future; and (2) to enable the contractor to analyze his expenditures with a view to improving his foremanship, class of laborers, plant equipment, and

the like." Both of these objects should appeal to the water-works superintendent, for he must frequently estimate the cost of extensions, and must also often stand in the position of contractor in carrying out such extensions with day labor.

It may be said without hesitation that Mr. Gillette has done a great service in preparing this exposition of the principles and methods of keeping detailed cost records; the data presented, relating to cost of work actually done, while valuable, are of much less importance than the suggestions relating to methods of keeping records and reducing costs. Indeed, sources of information in print are not very common, and usually give insufficient detail to be of much use, so the author had comparatively little to draw upon outside of his own wide experience. It is gratifying to note that a portion of the more valuable information given by the author has been obtained from papers read before this association.

TRADE PUBLICATIONS.

Allis-Chalmers Company, Milwaukee, Wis. — Pumping Engine Department.

Bulletin No. 1600, July, 1905. — Test and Record of the 30 000 000-Gallon Pumping Engine Installed in the Chestnut Hill High-Service Station of the Metropolitan Water Works, Boston, Mass. 8 x 10½ inches, 11 pages, 3 illustrations.

Bulletin No. 1601, July, 1905. — Test of One of the 15 000 000-Gallon Vertical Triple-Expansion Pumping Engines Installed in the Baden High-Service Station of the St. Louis, Mo., Water Works. 8 pages, 2 illustrations.

Bulletin No. 1602, September, 1905. — Centrifugal Pumps, Operated by Simple, Compound, or Triple-Expansion Engines. 8 pages, 2 illustrations.

Bulletin No. 1603, August, 1905. — Reynolds Triple-Expansion Pumping Engines. 4 pages, 1 illustration.

Bulletin No. 1605, September, 1905. — High-Duty, Horizontal, Double-Acting, Crank and Fly-Wheel Plunger Pump, Driven by Cross-Compound Reynolds Corliss Engine, Standard Type F. M. P. 8 pages, 4 illustrations.

Bulletin No. 1606, September, 1905. — Multi-Stage, High-Lift Centrifugal Pumps, Motor Driven. 8 pages, 3 illustrations.

Bulletin No. 1607, September, 1905. — High-Duty, Horizontal, Double-Acting, Crank and Fly-Wheel Plunger Pump, driven by Cross-Compound Reynolds Corliss Engine, Standard Type F. O. P. 8 pages, 3 illustrations.

Bulletin No. 1608, September, 1905. — Single-Stage Centrifugal Pumps, Motor Driven. 4 pages, 1 illustration.

Lock-Bar Steel Pipe. The East Jersey Pipe Company, 71 Broadway, New York, N. Y. 9 x 6 inches, 34 pages, 2 diagrams, 13 illustrations.

Raymond Concrete Piling. Raymond Concrete Pile Company, Chicago, Ill. 6 x 9 inches, 48 pages, 31 illustrations.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XX. June, 1906. No. 2.

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ENGINEERING CONSTRUCTION BY THE UNITED STATES RECLAMATION SERVICE.

BY M. O. LEIGHTON, CHIEF OF THE DIVISION OF HYDRO-ECONOMICS, UNITED STATES GEOLOGICAL SURVEY, WASHINGTON, D. C.

[*Read January 10, 1906.*]

There is a development going on in the West which many well-informed men believe to be of more importance to this country than the construction of the Panama Canal. Throughout the West there are thousands of people who have fought for its initiation and, having been successful, are now looking forward to its completion, and predicting, as a result thereof, the most remarkable era of advancement and prosperity that this country has ever beheld. In the East there is a bare handful of people who appreciate and understand; a few more have a vague, mistaken idea; but the vast majority of Americans east of Missouri River have no more information concerning it than they have with reference to the foreign policy of the King of Siam.

It has not been observed that this dearth of information upon the part of eastern people is confined to any one class or profession, and it has been a matter of surprise to find that so few eastern engineers, and especially those who have specialized in water-works construction, maintenance and operation, have thought it worth the effort to inform themselves concerning the greatest water-supply systems of the world, which are being constructed within their own country and which involve the expenditure of over thirty millions of dollars. This water-works construction is designed to change enormous areas in the Great American Desert

from places of desolation and whitened bones to places of prosperous homes and fertile fields, where millions of people will dwell, and where generations of Americans will grow up. It involves engineering projects in many respects unprecedented in magnitude, which have quietly and conservatively, but none the less quickly and definitely, been entered upon, and are even now in process of construction.

Two fifths of the area covered by the United States is arid. This statement means that upon that proportion of all our possessions exclusive of Alaska and insular territory, sufficient rain does not fall to make agriculture profitable. Some of this area is in the semi-humid belt, where there may be for a season rain enough to provide for the growth and maturity of a crop, but where, perchance, the season or successive seasons following will bring little or no moisture. Some of it is desert, extending mile upon mile in blinding white solitude without the semblance of a living thing. Some of it is wind-swept plain, as level as the ocean and quite as featureless, differing from the desert only by reason of its growth of hard, dry, woody grass, its knots of sage-brush, its mesquite bushes or its cacti. There is upland and mountain, canyon and mesa, and all is devoid of useful vegetation as the paved streets of an eastern metropolis. This barren principality is greater than the empire of ancient Rome, seven times as large as the domain of the German Emperor, and equal to thirty states of the size of New York. Much of this region must always remain in its present condition, but there are enormous tracts throughout the length and breadth of the arid belt which retain every requisite feature of climate and fertility save that of moisture.

On June 17, 1902, the United States Congress passed the Reclamation Law. It provides that all the moneys received from the sale of public lands shall be set apart for the construction of irrigation works. The experience of years had shown that it was the only possible means whereby millions of acres of desert waste could be made habitable, and upon which there might develop communities which would return to the country an added vigor and stability which would be a thousand fold more valuable than the money expended. In addition to this, it seemed especially fitting that the money received from the sale of public

lands should be expended in this way, because nearly all government land in the humid regions has been sold, and practically all that now remaining in government ownership is arid. The money so provided is not a gift to the arid belt, but a loan that draws no direct interest. The farmer who takes up public land in an irrigated area must pay for the cost of the irrigation system, or his proportionate part thereof. The payment must be made in ten annual installments without interest, and thus the Government is finally reimbursed for the actual expenditures made necessary by the construction of irrigation systems, and loses in the end only the theoretical interest on the money so used. At the end of the period of payment, the farmer is the sole owner of the water rights: they become appurtenant to his property. The law makes it one of the duties of the Secretary of the Interior to make examinations and surveys for appropriate irrigation works and to locate and construct them. He is further authorized to withdraw from entry all public lands which may be required for any system of irrigation, and also the land which may be irrigated from such system. The actual engineering work has been placed by the Secretary of the Interior under a corps of engineers which has been designated as the United States Reclamation Service.

A wise provision in the irrigation law is that which makes it necessary for the farmer to take up irrigated lands under the Homestead Act; that is, no single farm unit can consist of more than one hundred and sixty acres, and, to secure title, the farmer must be an actual resident upon the property.

This prevents enormous speculative operations by which companies or individuals with large capital may acquire tremendous tracts of lands, and thereby receive the benefits of government irrigation, to the exclusion of the individual provided with less initial capital. In other words, the terms of the statute were designed to provide for *homes* in the arid states, rather than to increase the values of the land for speculative purposes.

The location and the extent of the work already undertaken is set forth in Table No. 1. It will be seen that all of the states and territories represented in the arid belt are provided for with the exception of Oklahoma, in which reconnaissance work is now going on.

TABLE No. 1. IRRIGATION PROJECTS ALREADY UNDERTAKEN.

State.	Name of Project.	Acres Irrigable.	Allotment.
Arizona	Salt River	160 000	$3 850 000
California	Yuma	85 000	3 000 000
Colorado	Uncompahgre	100 000	2 500 000
Idaho	Minidoka	60 000	1 300 000
"	Payette-Boise	60 000	1 300 000
Kansas	Garden City	8 600	260 000
Montana	Huntley	30 000	900 000
"	Milk River	——	1 000 000
Montana *(2/3)	Lower Yellowstone	40 000	1 200 000
Nebraska and Wyoming	North Platte	100 000	3 330 000
Nevada	Truckee-Carson	120 000	3 000 000
New Mexico	Hondo	10 000	240 000
"	Carlsbad	——	600 000
"	Rio Grande	——	200 000
North Dakota (1/3)	Lower Yellowstone	20 000	700 000
North Dakota	Pumping plants	33 000	1 000 000
Oregon	Klamath	100 000	2 000 000
"	Umatilla	18 000	1 000 000
South Dakota	Belle Fourche	60 000	2 100 000
Utah	Strawberry Valley	25 000	1 250 000
Washington	Okanogan	9 000	500 000
"	Yakima	40 000	1 750 000
Wyoming	Shoshone	75 000	2 250 000
		1 153 600	$35 230 000

* For dam in St. Mary; will not irrigate any land.

It will be impossible to discuss within the time allotted for this paper the constructive features of all the projects named in this table. Therefore attention will be given to those which comprise the most interesting features.

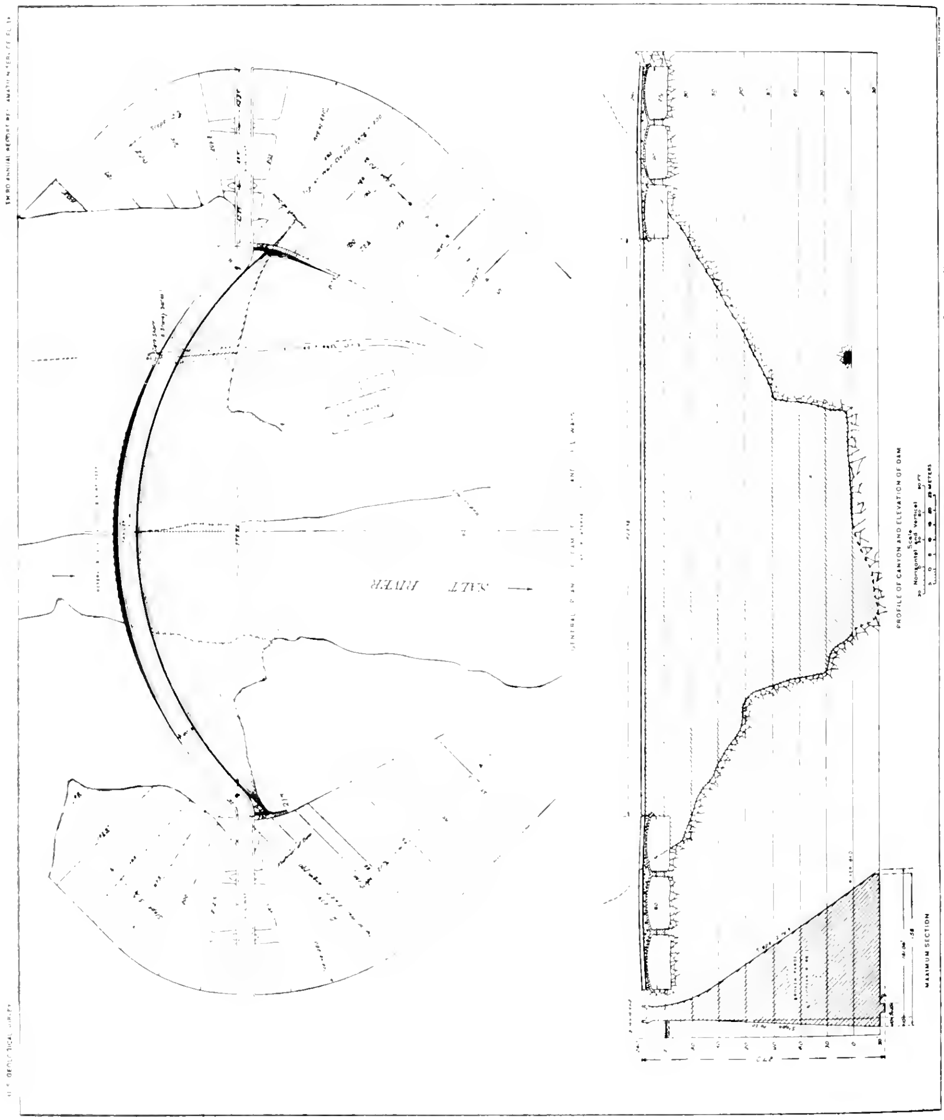
SALT RIVER PROJECT, ARIZONA.

The area to be irrigated under this project lies in the lower valley of Salt River in the region about Phœnix, Tempe, and Mesa, while the storage reservoir, the largest artificial lake in existence, lies to the northeast about seventy miles from Phœnix. The water stored in the reservoir is to be released as required for irrigation and allowed to flow down the bed of the river to a point near the head of the irrigated area, where it will be diverted into properly constructed canals. About 160 000 acres in this lower valley will be irrigated under gravity canals, while the remainder

will be provided for by pumping water on the higher levels with power derived from a plant located at the reservoir dam. The reservoir will cover what is known as the Tonto Basin, a great depression formed by the valleys of Salt River and Tonto Creek, the two streams joining a short distance above the dam site. (Plate 1, Fig. 1.) The extreme length of this reservoir will be 25 miles, its greatest depth of water 230 feet, and its capacity 61 000 000 000 cubic feet, or about 456 000 000 000 gallons, sufficient to supply the Metropolitan water system in Massachusetts at the present rate of consumption for a period of ten and one-half years.

Salt River enters a canyon a short distance below the confluence of Tonto Creek. Across this canyon, at the section shown in Plate 1, Fig. 2, a dam, known as the Roosevelt Dam, is in process of erection which will have a total height from foundation to top of parapet of 280 feet, and an effective storage height of 230 feet. (See Fig. 1.) The length of the dam at datum, or low water, will be 138 feet, and at the crest, 644 feet. The section of the dam provides for a masonry wall 158 feet thick at the base, tapering as indicated to a thickness of 16 feet at the crest. There will be about 300 000 cubic yards of masonry in the structure.

The dam has a gravity arch section, the radius being 400 feet. A roadway is carried over the dam, crossing the spillways on each side by concrete-steel arch bridges. The total height of the spillway above datum or mean low water will be 230 feet, while the roadway will be 20 feet higher. The spillways are each about 200 feet long, providing for a total discharge of 4 000 cubic feet per second. The specifications require that the masonry shall be of broken range cyclopean rubble, laid so as to break joints and be thoroughly bonded in all directions. The stone will be quarried from the walls on each side of the canyon for the spillways, and will be laid in cement mortar. The material is a tough, coarse-grained sandstone of a specific gravity of about 2.5. Samples of the stone crush at a pressure of from 1 000 to 1 800 tons per square foot, which affords an exceedingly wide margin of safety. The stone for the up-stream face will be selected so as to lie with horizontal beds and vertical joints in



GENERAL PLAN, ELEVATION AND SECTION OF THE ROOSEVELT DAM. SALT RIVER PROJECT, ARIZONA.

FIG. 1.

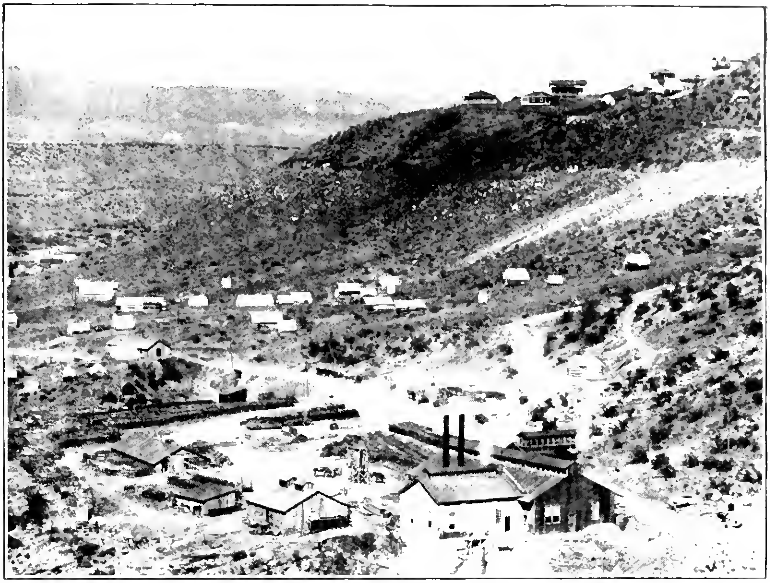


FIG. 1. TONTO BASIN (SALT RIVER), ARIZONA.

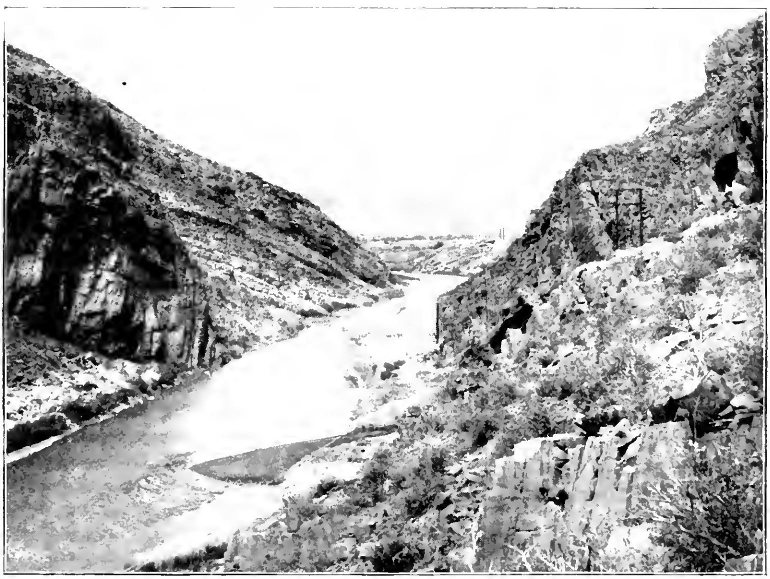


FIG. 2. SITE OF ROOSEVELT DAM (SALT RIVER).

Portland cement mortar composed of one part Portland cement and two parts sand. Vertical joints between the stones inside of the face of the dam must nowhere be less than six inches. The concrete used in the construction of the dam is composed of one part cement, two and one-half parts of sand and four parts of broken stone. The term "sand" is interpreted as the run of the crusher which passes a quarter-inch screen, while "stone" is interpreted as that which passes a two-inch mesh.

In order to provide for the rights of prior appropriators, it is necessary to guarantee the release of a certain amount of water into the river channel at all times. To accomplish this and to utilize the power available at the dam site, a low diversion dam has been constructed across Salt River above the upper reaches of the overflowed areas, and in seasons of low water the entire flow of the stream will be diverted around the reservoir by means of a conduit 19 miles long. A part of this conduit is in heavy cut, some of it on fill, while 9 000 feet consists of tunnels, 15 in number through clay, sand, quicksand, and solid rock. Fourteen of these tunnels are along the power canal and one is a sluicing tunnel at the dam site.

Tunnel No. 1 at the point of diversion is 1 700 feet in length and afforded more difficulties of construction than any of the others. For 600 feet it passed through bowlders that were imbedded in quicksand and varied from small cobbles to masses weighing several tons. As this sand would run like water, heavy timbering was provided. The finished section of this tunnel has a width of 9 feet and a height of 8 feet to the apex of the arch, but in order to allow for the timbers the excavation was made 12 feet wide and 11 feet high. Square sets of 10-inch timbers were placed two feet apart from center to center and inside each of these an arched set was placed for extra strength as well as to give a proper section to the tunnel. The breast of the tunnel had to be boarded solid and the lagging driven ahead for each following set. The greatest difficulty occurred when big bowlders were encountered. These had to be dealt with separately and worked an inch at a time, regardless of size or condition, as any attempt to break them with powder would have caused a cave or a run. This 600 feet of bad ground was worked with four

headings with 2 shifts each, and an average of 6 feet per day was made from the four headings.

Quicksand was encountered elsewhere in the work, but was not as difficult as at tunnel No. 1.

The last tunnel to be constructed was the penstock. This is a circular tunnel, 620 feet long and 8½ feet in diameter: it has a fall of approximately 200 feet from the mouth of the canal to the turbine. Before work was begun on this tunnel it was necessary to excavate, out of the perpendicular cliffs, a site for the power plant, which is 23 feet above the river. The tunnel starts at the back of the power plant at the elevation of the floor. Work was begun at the lower end of the penstock by hand, as floods in the river made the temporary power plant useless. For two months the materials and supplies were packed in on the shoulders of men, along precipitous canyon sides, shelving rock and rolling bowlders, and passed down the vertical cliffs by ladders and ropes. In this way 110 feet of the tunnel was driven. Later, after the floods had subsided, the work was carried on more expeditiously by means of power. Notwithstanding the fact that an exhaust fan with 7-inch piping was used, the heat and gas were intense. It is a peculiarity of this climate and elevation that all underground raises have no ventilation. In this tunnel the heat was unusual, due to the proximity of subterranean hot springs.

The sluicing tunnel around the base of the dam is 13 feet wide, 11 feet high, and 480 feet long, and it is carried through solid quartzite and sandstone. The heat here was intense and caused the death of two of the men; several hot springs were encountered and the temperature rose to 130° Fahrenheit, with practically 100 per cent. humidity.

The cost of the masonry construction of the dam is \$3.15 per cubic yard, or a total for the entire structure of \$1 147 600. This cost is exclusive of cement and sand, which are furnished by the Reclamation Service from the Government cement mill near the dam site, which will be described later. The total cost of dam, allowing \$2.50 per barrel for cement, is over \$2 000 000. The cost of the power tunnel was \$26.50 per linear foot.

One of the best pieces of construction connected with the Salt River project is the sluicing tunnel and gates. (Fig. 2.) In

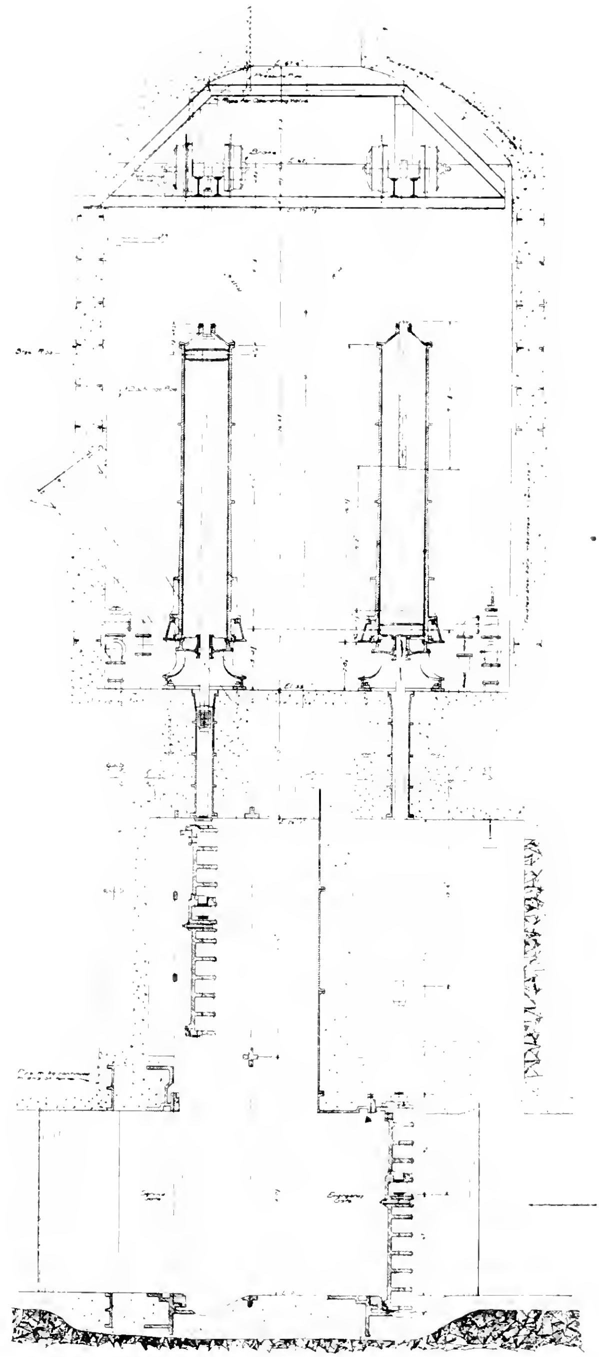


FIG. 2. SLUICING GATES AT ROOSEVELT DAM.

this tunnel will be placed six gates to be used for sluicing purposes and for regulating the flow of the water to the canals of Salt River Valley. These gates with their operating mechanism will weigh nearly 800 000 pounds, and will be the largest ever constructed to operate under the great pressure of 100 pounds per square inch. The pressure on each gate is about 800 000 pounds. With the reservoir full, these gates are capable of discharging 10 000 cubic feet per second. During the construction of the dam, the river will be diverted through this channel. It will not be possible in the time allotted for this paper to discuss the details of construction. Indeed, the subject is worthy of a separate paper.

One of the interesting features of this project is the Government cement mill, constructed near the dam site. It was not originally the purpose of the Reclamation Service to enter into the manufacture of cement, but it was found that the cost of cement shipped to this site would be prohibitive. The nearest railroad point is Globe, Ariz., which is not within easy access of any of the cement works. The freight rates to this terminal point are high, and the transportation overland for forty miles to the dam site would add excessively to the cost. The bids which were received for furnishing cement were $4.81 per barrel, delivered at the dam site. As the construction required 200 000 barrels of cement, the cost of the work would be prohibitive. It was found, however, that cement materials were available at or near the dam site; a good cement rock underlies the mill and suitable clay is available a short distance away. It was therefore decided to erect a mill, at a cost of $100 000. The cement manufacturers naturally objected to this move, but it was conclusively shown that if it were necessary to purchase cement at the price at which it could be delivered at the dam site, the cost of the structure would be wellnigh prohibitive, while the erection of the cement mill and the manufacture of the material upon the spot would result in an enormous saving. In view of the fact that cement manufactured at this mill costs $2.50 per barrel, the Government could hardly afford to haul purchased cement from Globe to the dam site, even if the material were delivered at Globe free of cost. The mill finally erected has a capacity of 350 barrels per day.

The chief item of expense is that of fuel, it being necessary to haul oil in wagons from Mesa, Ariz., a distance of about fifty miles. Average results of tensile tests of neat cement briquettes are: 478 pounds after seven days (one day in air and six days in water): 552 pounds after fourteen days.

The Uncompahgre Project.

The Uncompahgre Valley comprises an area in Ouray, Montrose, and Delta counties in the southwestern part of Colorado. It is watered by Uncompahgre River, which flows northward and joins Gunnison River at Delta. In this valley there are about 75 000 acres which early experience proved to be exceedingly fertile under irrigation. (Plate II, Fig. 1.) Consequently, in about 1884 settlers flocked to the valley and filed upon nearly all the land in the region. Irrigation canals were constructed and what was believed to be a mighty era of prosperity was begun. It was soon found that all this development was made without any idea of the amount of water in Uncompahgre River available for irrigation. The river did not begin to furnish sufficient supply. After a time great tracts were deserted, costly improvements abandoned, and the acres under cultivation soon dwindled to 30 000.

Thirty miles eastward from Uncompahgre River and flowing nearly parallel to it is the Gunnison (Fig. 3), which farther to the north takes an abrupt westward turn and is joined by the Uncompahgre at Delta. Along this portion of the Gunnison parallel to the Uncompahgre, the river traverses the Grand Canyon (Plate III, Fig. 1), one of the best scenic features of the West and at the same time one of the most difficult places of access.

The method of solution of the Uncompahgre problem which found most favor was the tapping of the Gunnison by a tunnel opening at the bottom of this canyon and extending underground six miles to a point in the Uncompahgre Valley from which the water could be carried in open canals. Up to the time of the official investigation nothing was known concerning Gunnison Canyon save that its walls rose sheer 3 000 feet, that a torrential stream ran through the bottom, and that it was impassable. So far as was known, no man had ever passed through

this canyon alive. It was necessary to know, first, the conditions existing in the canyon and whether or not, were all the other difficulties overcome, it would be possible to open a tunnel heading. A voyage through the canyon was necessary, and

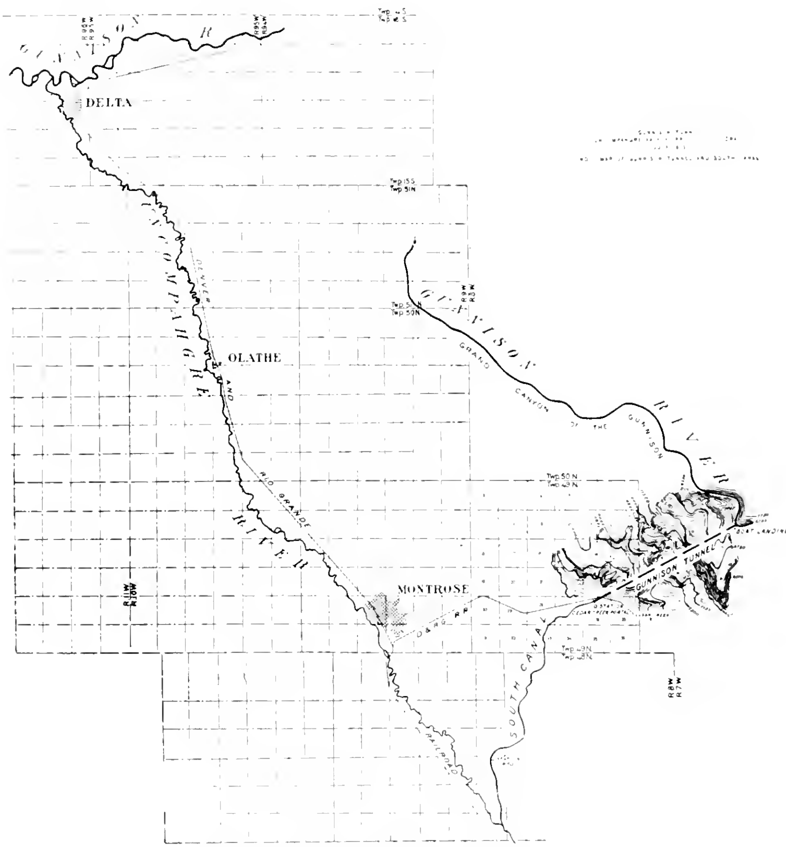


FIG. 3. MAP SHOWING LOCATION OF GUNNISON TUNNEL.

it was undertaken and accomplished by Mr. A. L. Fellows, at that time district engineer for Colorado. In spite of the difficulties and dangers attendant upon the journey, Mr. Fellows' observations resulted in the selection of a heading just above the point at which the canyon boxes up.

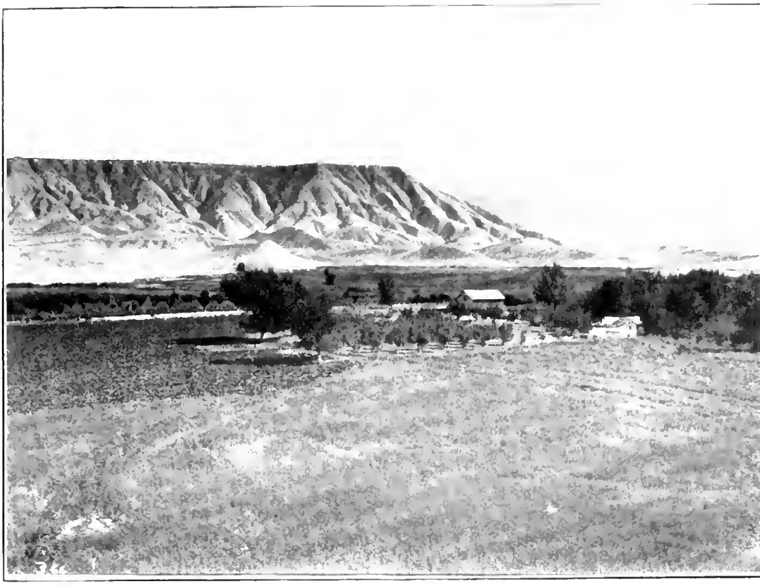


Fig. 1. Uncompahgre Valley under Irrigation.

Fig 2. Site of Pathfinder Dam (North Platte River).

PLATE III.

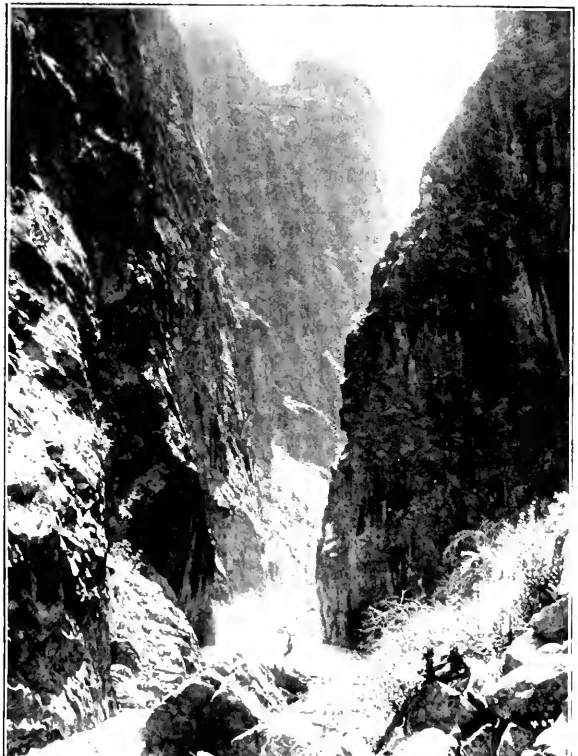


FIG. 1. CANYON OF THE GUNNISON.

FIG. 2. SITE OF SHOSHONE DAM.

In Fig. 4 is shown the tunnel profile. When finished it will be 30 582 feet long, and of a capacity of 1 300 cubic feet per second. The total excavation will be 183 500 cubic yards, of which 93 000 cubic yards will be in rock. The total amount of lining will be 30 000 cubic yards, laid at a cost of $6.75 per cubic yard. The cost of the tunnel and other rock is $40 per linear foot, while the total cost of the tunnel will be $1 200 000.

North Platte Project.

The land to be irrigated under the North Platte project lies in southeastern Wyoming and western Nebraska along the North Platte River Valley, as shown in Fig. 5; the total acreage irrigable will be 100 000. The water is to be conserved in the Pathfinder reservoir.

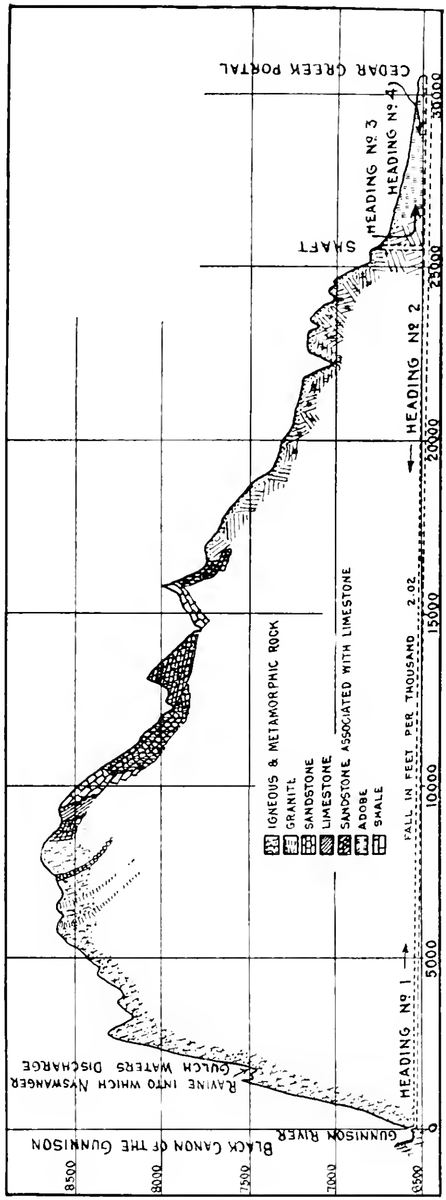


Fig. 4. Profile of Gunnison Tunnel.

and, being discharged from there, will flow sixty miles in the stream bed and then be diverted into the Interstate Canal, which conducts the water into the area in question. The point of interest in this project from the engineering standpoint is the Pathfinder Dam and appurtenant works.

The dam called the Pathfinder Dam is located across the channel of North Platte River in Wyoming, three miles below the mouth of Sweetwater River, where the Platte enters the canyon cut through Rattlesnake Range. (Plate II, Fig. 2.) Here the

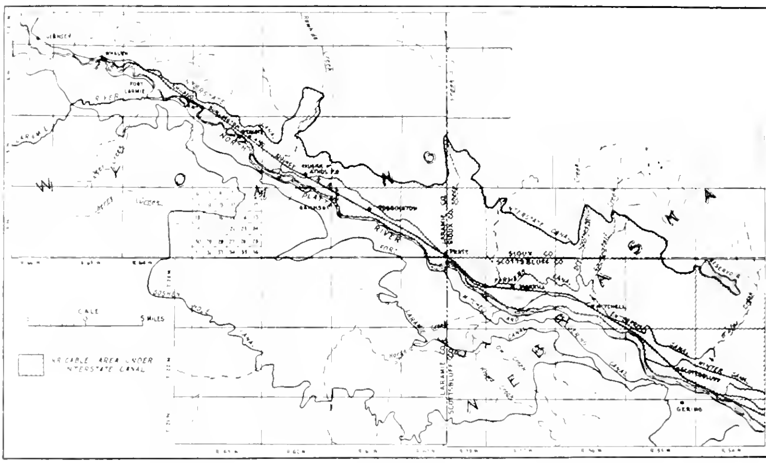


FIG. 5. MAP SHOWING INTERSTATE CANAL, NORTH PLATTE PROJECT.

gorge is 80 feet wide at low-water mark and but 180 feet wide at a point 160 feet above Datum. The walls are of solid granite, and bed rock without seam or fracture occurs 10 feet below low-water mark. Fig. 6 shows a cross-section of the gorge with dam in place, and a cross-section of the dam which is being constructed of granite in broken range cyclopean rubble. The total amount of masonry will be 53 000 cubic yards. The specifications provide that the masonry shall be laid so as to break joints and thoroughly bond the work in all directions. The stone used is as large as practicable, and facilities are provided for handling stones weighing ten tons. The aim is to use in the construction

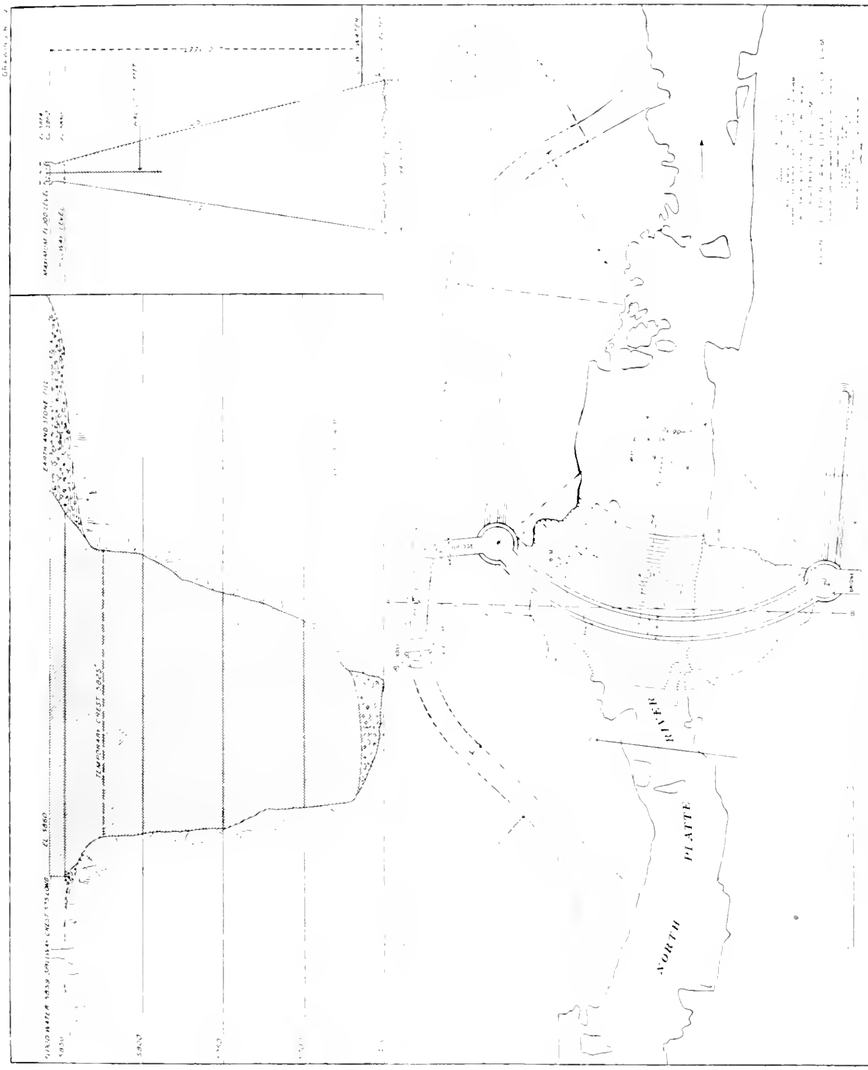


FIG. 6. PATHFINDER DAM.

of the dam the largest proportion of stone and the smallest proportion of mortar and concrete. The stone for the up-stream face is selected so as to lie with horizontal beds and vertical joints in Portland cement mortar composed of 1 part cement to 2 parts sand. At least one fourth of the area in the face must be headers, evenly distributed throughout the wall, and every header must be laid over a stretcher of the underlying course. The stretchers must not be less than 3 feet long nor less than 2 feet in any other dimension. The headers must not be less than 6 feet in length nor less than 2 feet in any other dimension. The stone for the down-stream face is selected so as to lie with horizontal beds and vertical joints in cement mortar composed of sand and cement in the proportion of 1 part cement to $2\frac{1}{2}$ parts sand, where not otherwise directed. At least one fourth of the area in the face must be headers. All concrete used in the dam is composed of the proportion of 1 part cement and $2\frac{1}{2}$ parts sand and 4 parts of broken stone of such size as to pass through a 2-inch mesh screen. Sand in this case is considered that part of the run of the crusher passing a $\frac{1}{4}$-inch screen.

The dam (Fig. 6) is of arch type, constructed on a radius of 150 feet. It is 10 feet thick at the crest, 94 feet thick at the base, and 210 feet high. The batter of the up-stream face is 0.15 and of the down-stream face, 0.25. The masonry is reinforced by steel rails at points at and below the crest where special horizontal and vertical stresses will develop.

In may be considered by some that this dam is of very thin section, but it conforms to the principles established by a long series of elaborate experiments made under the direction of the board of consulting engineers of the United States Reclamation Service, the work being executed under the immediate direction of Mr. George Y. Wisner, a member of the Board. For a discussion of these experiments see *Engineering News*, issue of August 10, 1905, p. 141 *et seq*.

The maximum depth of water behind Pathfinder Dam will be 200 feet, and the amount of water stored will be 326 000 000 000 gallons. The contract price for the complete structure is $582 000. As will be noted upon the plan, the outlet of the reservoir will be through a tunnel cut through the walls of the canyon, and

through this the river is diverted during construction. The spillway is provided on the right bank of the canyon so that the dam is a solid structure without gates or openings, and no water will flow over the top.

The Shoshone Project.

This project contemplates the storage and diversion of a portion of the surplus water of Shoshone River in Wyoming for the reclamation of public lands lying on the north side of the river, extending from the mouth of the Shoshone Canyon down stream about 50 miles, covering an area of approximately 282 000 acres. The present development is proposed to reclaim only 125 000 acres. Just below the junction of its two forks, Shoshone River enters a canyon 3 miles in length, 1 mile of which is cut in solid granite with nearly vertical walls and it is about 65 feet wide in its narrowest places. The point selected for the dam site (Plate III, Fig. 2) is 70 feet wide on the bottom of the channel and 200 feet wide at an elevation of 240 feet, the proposed height of the dam above the river bed. (Fig. 7.) This provides for a dam of a height from lowest foundation to capstone of from 305 to 310 feet, it being the highest dam in the world, both in total height and effective storage height. The capacity of the reservoir formed thereby will be 14 858 000 000 gallons, or a little less than one half of the storage capacity afforded by the Pathfinder Dam and a little more than one third that afforded by the Roosevelt Dam. The spillway will be 250 feet in length, the weir being located a few hundred feet below the dam on the side of the canyon, and connection therewith from the reservoir will be made by the construction of a spillway tunnel of a capacity of 10 000 cubic feet per second.

A tunnel for the public highway will be cut out of the same side of the canyon and will cross this spillway tunnel twice at an elevation of about 45 feet above the average elevation of the spillway tunnel floor. The dam as shown in the illustration will be of the arch type upon a radius of 150 feet. (Fig. 8.) It will be noted that the dam is being constructed 108 feet thick at the base and 10 feet thick at the crest, with an up-stream batter of 15 per cent. and a down-stream batter of 25 per cent.

As shown upon the illustration, a vertical section of the dam having an effective storage height of 31 feet will be constructed in advance of the main portion for the purpose of diverting water from the excavation. The section of this dam is based upon experimentation in the same way as has been discussed in the

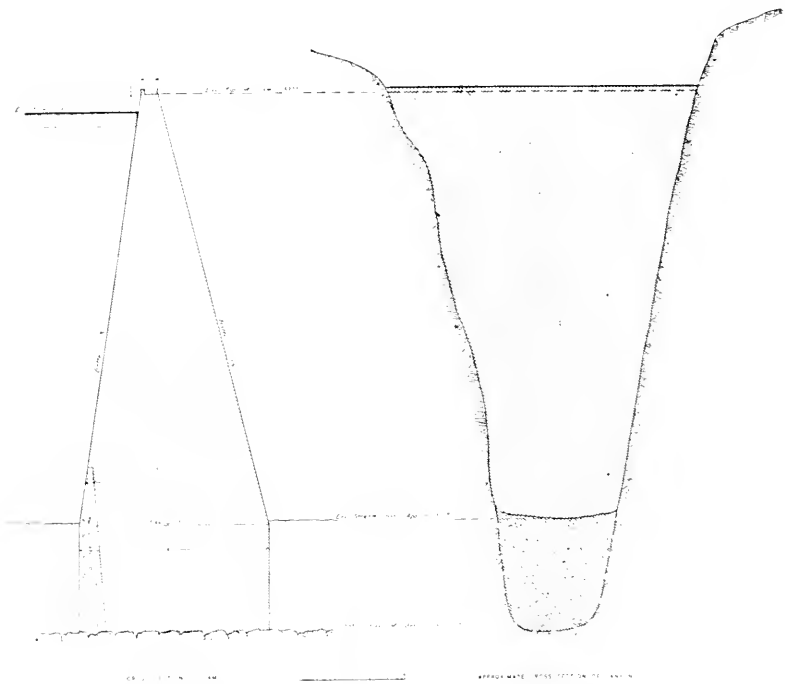


FIG. 7. SECTION AND ELEVATION OF SHOSHONE DAM.

case of the Pathfinder Dam, a thin section with an uncommonly large up-stream batter for this kind of structure.

The dam is being constructed of concrete of a composition, where not otherwise specified, in the proportion of 1 part cement, 2½ parts sand, and 5 parts of broken stone. The term "sand" is interpreted as that portion of the run of the crusher which shall pass a screen of ¼-inch aperture, the proportion of finer particles being such that the void in the dry aggregate shall not exceed 30 per cent. of the mass. The stone used in the crusher

is granite taken from the sides of the canyon and other suitable places. The concrete will be reinforced by steel and iron rails in such portions of the dam as will by reason of horizontal and vertical stresses require such reinforcement. It is provided in

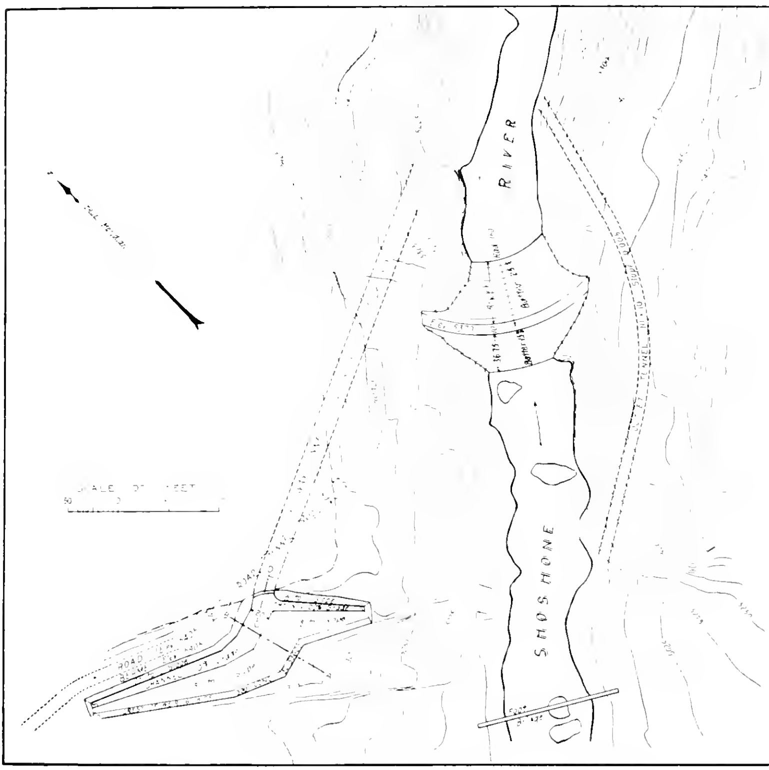


FIG. 8. PLAN OF SHOSHONE DAM AND TUNNELS.

the specifications that both faces of the dam shall be molded against forms of dressed tongued and grooved timber placed to conform to lines established by the engineer. The concrete shall be so placed against these forms and so manipulated as to secure a smooth, dense, and uniform facing of the dam. The contract further provides that in the freshly deposited concrete

the contractor shall place by hand pieces of granite weighing between 25 and 200 pounds, which shall be rammed until well bedded. The proportion of such rocks shall be as nearly as possible uniform throughout the dam and shall form at least 25 per cent. of the total volume of masonry. No such rock shall be in contact with any other or within 6 inches of either face or either abutment of the dam. The work will be done with three daily shifts of eight hours each, and the contractor is required to adopt means to provide such appliances and housing as will permit the construction of the masonry work during cold weather. Such provisions shall maintain the temperature within 6 inches of the concrete until it is ten days old at not less than 32° F.

There will be two outlet conduits leaving the reservoir, one at 10 and one at 60 feet above the river bed. The one leaving the reservoir at the elevation of 10 feet will be by a tunnel through the side of the canyon 500 feet in length and 10 by 10 feet in cross-section, and will discharge the water from the reservoir into the low-level canals.

The total cost of the Shoshone Dam, including outlet tunnel, spillway tunnel, spillway and road tunnel, will be $600 000. The cost and dimensions of the three masonry dams here described compared with similar figures for the New Croton and Wachusett dams are set forth in the following table:

TABLE No. 2.

	Roosevelt Dam.	Pathfinder Dam	Shoshone Dam	New Croton Dam	Wachusett Dam
Length at crest	650	226	175	1 168	850
Height above foundation	280	210	308	297	207
Maximum effective storage height	230	190	240	157	185
Thickness at base	158	94	108	206	185
Thickness at crest	16	10	10	18	25
Cu. yds. of masonry	350 000	53 000	69 000	833 000	280 000
Capacity of reservoir (million cu. ft.)	61 000	43 560	19 863	4 000	8 400
Cost of dam	$2 000 000	$600 000	$700 000	$7 600 000	$2 000 000
Cost of dam per million cu. ft. stored	$32 80	$13 78	$35 25	$1 900 00	$238 10

It should be explained that the last entry upon this table does not represent the cost of storage per million gallons, but is based solely upon the cost of the dam. The total cost for storage in the Roosevelt basin, exclusive of power conduit and appurtenances, will be about $2 500 000, in which only about $85 000 is for land damages. In the case of the Wachusett Dam, the figure here given for cost per million gallons must be multiplied by about 4 to cover cost of entire reservoir.

NOTE. — The Belle Fourche Project and the large earthern dam to be erected in connection therewith are described in *Engineering News*, February 22, 1905, p. 210, and *Engineering Record*, March 3, 1905, p. 307.

DISCUSSION.

MR. CHARLES W. SHERMAN. I should like to ask Mr. Leighton if he can tell us something about the run-off of those streams, and how much water they can depend upon collecting per square mile of drainage area, or something of that kind.

MR. LEIGHTON. The run-off at some of the principal arid land stations is as follows:

TABLE NO. 3. RUN-OFF OF RIVERS IN THE ARID REGION — FOR THE YEAR 1904.

Stream.	Station.	Second Feet per Sq. Mi.	Depth in Inches.	Drainage Area Sq. Mi.
Salt River	Roosevelt, Ariz.	.057	.785	5 756
Verde River	McDowell, Ariz.	.062	.843	6 000
Colorado River	Yuma, Ariz.	.062	.844	225 049
Gunnison River	Cory, Col.	.328	4.47	5 233
Humboldt River	Palisade, Nev.	.109	1.48	5 014
" "	Oreana, Nev.	.021	.288	13 800
Truckee River	Vista, Nev.	1.30	17.72	1 519
Carson River	Empire, Nev.	.737	10.02	988
Rio Grande River	San Idlefonso, N. Mex.	.071	.972	14 050
North Platte River*	Mitchell, Neb.	1.113	1.208	24 400
Milk River	Malta, Mont.	.028	.374	14 044
Shoshone River	Cody, Wyo.	1.28	17.44	1 480
Yellowstone River	Livingston, Mont.	1.286	17.523	3 580
Snake River	Minidoka, Ida.	.559	7.61	22 600
Palouse River	Hooper, Wash.	.382	5.20	2 210

* Eight days in January; sixteen in February; five in March, not included.

It may be of interest to compare the run-off of some of these rivers with some in the East.

TABLE No. 4. COMPARISON OF RUN-OFF OF RIVERS FOR THE YEAR 1904.

Stream.	Station.	Second Feet per Sq. Mi.	Depth in Inches.	Drainage Area Sq. Mi.
Yellowstone River	Livingston, Mont.	1.286	17.523	3 580
Connecticut River	Orford, N. H.	1.32	16.11	3 305
Palouse River	Hooper, Wash.	.382	5.20	2 210
Hudson River	Ft. Edward, N. Y.	1.97	26.74	2 800
Shoshone River	Cody, Wyo.	1.28	17.11	1 480
Mohawk River	Little Falls, N. Y.	2.27	30.96	1 306
North Platte River	Mitchell, Neb.	1.113	15.208	24 400
Susquehanna River	Harrisburg, Pa.	1.350	18.320	24 030
Verde River	McDowell, Ariz.	.062	.843	6 000
James River	Cartersville, Va.	.731	9.980	6 230

MR. FRANK L. FULLER. I should like to ask with regard to the evaporation from those lakes.

MR. LEIGHTON. That is one of the very important questions with which the Reclamation Service has to deal. Especially in the southern country, like Arizona, the evaporation is enormous.

TABLE No. 5. EVAPORATION FROM WATER SURFACE, IN INCHES.

	Arizona, 1890.	Yuma, Ariz., 1904.	Sweetwater, Cal., Dam, 1898.	Lake Tahoe, Sierra Nevada Mts., Cal., 1901.	El Paso, Texas, 1890.	Santa Fé, N. M.	Salt Lake City.
January	3	3.6	1.747	0.81	2.0	3.0	1.8
February	4	3.9	2.671	0.70	2.0	3.4	2.7
March	6	6.19	4.249	0.77	7.0	4.2	3.6
April	7	9.37	5.351	1.25	7.3	6.8	7.2
May	10	9.91	5.611	2.42	10.8	8.8	6.9
June	11	10.11	7.193	3.35	11.7	12.9	8.9
July	12	10.19	8.153	—	9.6	9.2	9.2
August	13	7.87	8.111	6.50	7.6	9.8	10.7
September	10	6.38	7.239	4.12	—	6.6	9.6
October	6	7.02	4.999	2.65	—	6.7	6.5
November	5	4.41	4.012	2.09	3.7	5.7	5.0
December	4	1.91	.867	1.44	3.0	2.7	2.3
Total	91	80.89	60.233	*26.13	—	79.8	74.4

* Eleven months.

and it becomes an important item in calculating the amount of water available from storage. The following figures may be of interest. Evaporation is given in inches per year from water surfaces.

MR. FULLER. Can you tell us what the average rainfall is for a series of years?

MR. LEIGHTON. The United States Weather Bureau reports for 1904 the precipitations in arid regions as follows:

TABLE NO. 6. RAINFALL IN THE ARID REGION, 1904.

	Precipitation for Year.	Departure from Normal.
El Paso, Texas	11.30	+1.96
Santa Fé, N. M.	14.19	—0.09
Phœnix, Ariz.	5.57	—1.38
Yuma, Ariz.	1.43	—1.55
San Diego, Cal.	6.61	—3.98
Spokane, Wash.	13.97	—4.35
Grand Junction, Col.	6.63	—1.90
Winnemuca, Nev.	9.44	+0.93
Salt Lake City, Utah	16.31	+0.07
Boise, Ida.	14.08	—0.40
Carson City, Nev.	10.52	—1.50

It should be stated with reference to the arid lands generally, that the precipitation, from an agricultural point of view, is not even as useful as would appear from the above figures, because in many places the rain comes in short periods and in great quantity, with long dry seasons intervening.

MR. JOHN C. WHITNEY. I should like to ask the speaker what the special object was of distributing those large fragments of granite throughout the concrete construction shown.

MR. LEIGHTON. Such construction is familiarly known as rubble concrete, or, in such structures as the Shoshone Dam where the stones are of large size, a more comprehensive term is cyclopean rubble concrete. The main object is to increase the weight of the dam and thereby increase its stability. The specific gravity of granite is greater than that of concrete. There is an important economic feature, too, in such construction, because the rock is usually cheaper than the cement materials

and the cost of the structure is decreased by a proportionate amount. In all the contracts let by the Reclamation Service, cement is provided by the Government, and the contractor submits bids without taking cement into consideration. Therefore, you can readily see how advantageous it is to put large stone blocks into the structure, where rock is cheap. Twenty-five per cent. of the entire structure of Shoshone Dam will be of stone. As the formula for the concrete is 1 part cement, $2\frac{1}{2}$ parts sand, and 5 parts stone, and there will be 70 000 cubic yards in the dam, it would require a little over 96 000 barrels of cement for the entire structure, if it were built of concrete, but, inasmuch as 25 per cent. of the dam will consist of stone, there will be saved 24 000 barrels of cement by using this method.

MR. SIDNEY SMITH. When the storms do occur, when the rain falls, do the streams not carry a large quantity of detritus, and has any arrangement been made to relieve the reservoir of that?

MR. LEIGHTON. They do carry enormous amounts. Some of the engineers who were working on Gila River used to state in a joking fashion, when they came back to Washington, that it was hard for them to distinguish between mud and water. By placing a stick upright in the material they could decide, because if it was mud the stick would stand up, and if it fell over, they knew it was water. (Laughter.) The fact that the streams do carry these great amounts of sediment presents another very perplexing problem for the Reclamation Service. Of course, the accumulation in a reservoir reduces the effective storage capacity. The Salt River reservoir, for example, will probably lose a large proportion of its capacity in, say, sixty years, and the reason for extending the dam 10 feet higher was to postpone the day when remedial measures would be necessary. In all such cases, there have been provided enormous sluicing gates, through which the accumulations may be removed. Ground sluicing may be necessary to clear the reservoir in a large measure of this sediment. Lake McMillan, in New Mexico, which is a reservoir built by a private company, has lost a very large percentage of its storage capacity, and that is not yet a very old reservoir. But in every case, as I say, provision for sluicing is made. It may be necessary once in a generation and the cost will be high, but

such cost will be insignificant in proportion to the benefits of the reservoir and of the irrigation system, so that the property will easily afford the expense.

Mr. Smith. Will the cleaning out of the reservoirs at such times involve an expense to the owners of the land who use the water?

Mr. Leighton. Yes, sir. In ten years the property goes into the hands of the farmers, or, more correctly, into the control of the Water Users Associations, and they will maintain it thereafter. Those expenses will be provided for probably by the establishment of a sinking fund.

Mr. Fuller. I should like to ask Mr. Leighton if it is necessary that this water, as it is used for irrigating, shall be reasonably free from sediment, or what the fact is with regard to it?

Mr. Leighton. No. If the sediment is properly handled, if it is merely what we call silt, it is a benefit to the property. You see the great portion of that country is sand, gravel, and coarse material, which is benefited by these deposits of silt. Take the Colorado River, for example, that is in a good many ways exactly similar to the Nile in its annual inundations and deposits of silt, and it has made the barren sand so rich that one farm hand cannot take care of more than 10 acres of land, because the crops grow so fast. They are raising all sorts of tropical fruits and have had considerable success lately with date palms, pomegranates, figs, almonds, and such things.

THE PITOMETER AND ITS USES.

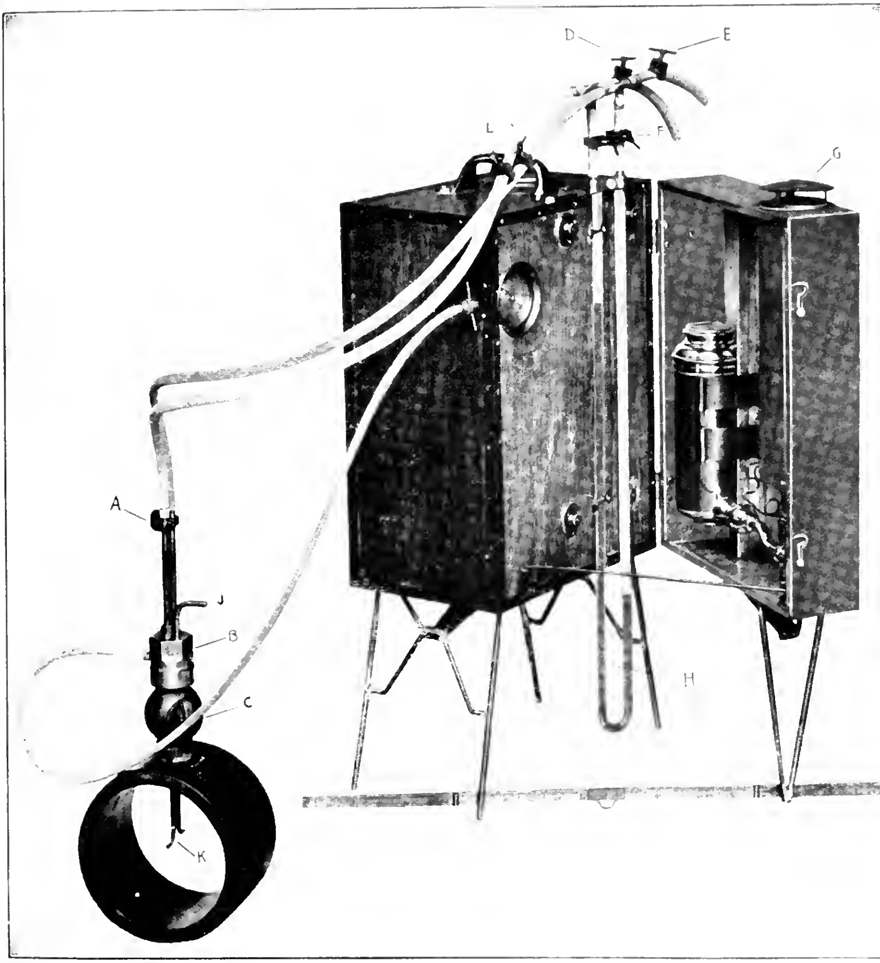
BY EDMUND M. BLAKE, CIVIL ENGINEER, BOSTON, MASS.

[*Read March 14, 1906.*]

In 1896, John A. Cole, consulting engineer of Chicago, found it necessary to make a water-waste survey at Terre Haute, Ind. He decided that it would be advisable to find some more economical method of measuring the waste flow than by use of the Venturi or Deacon meter. Edward S. Cole, associated with his father, finally acted upon a suggestion obtained from Prof. R. C. Carpenter's work on "Experimental Engineering," regarding the Pitot tube as applied to water mains. The use of the Pitot tube in open stream work is doubtless familiar to all engineers and superintendents.

Mr. Cole had to contend with many difficulties in adapting this principle to the measurement of velocities in closed pipes. Two tubes were finally adopted which could be introduced through a 1-inch corporation cock by means of a special cap, each tube with a hook bent 90 degrees and provided with a "cut-water." The two points of contact with the current are called orifices — one points down stream and the other up stream, as shown in Fig. 1. Many long series of calibrations were made with orifices and tubes of various diameters, but finally a choice was made of an orifice having an internal diameter of $\frac{1}{8}$-inch, made of 3-16-inch brass tubing, fitted to $\frac{1}{4}$-inch tubes. It was found that an orifice and tube of this size gave more reliable indications at low velocities, and that there was less trouble with negative readings or failure to return to equilibrium at no flow.

A glass U-tube, 22 inches long and having an internal diameter of $\frac{5}{16}$ inch, was used. Connections were made by $\frac{1}{4}$-inch rubber tubing, and a blow-off was located at the top of each connection to remove air. The lower half of the U-tube was filled with a mixture of carbon tetrachloride and gasoline, with a specific gravity of 1.25 or 1.50 at ordinary temperatures. For high



THE PITOMETER WITH PHOTO-RECORDER.

velocities mercury is used. Careful notes were made of the temperature at which observations were taken, and temperature corrections were applied where found necessary. Plate I shows a complete pitometer set up, with the "orifices" in position in a section of water pipe.

It was found that photography was the only practicable means of registering continuously the deflections in the U-tube, without interfering with those deflections. The photo-recorder combines, upon one photographic diagram, a record of the static variations

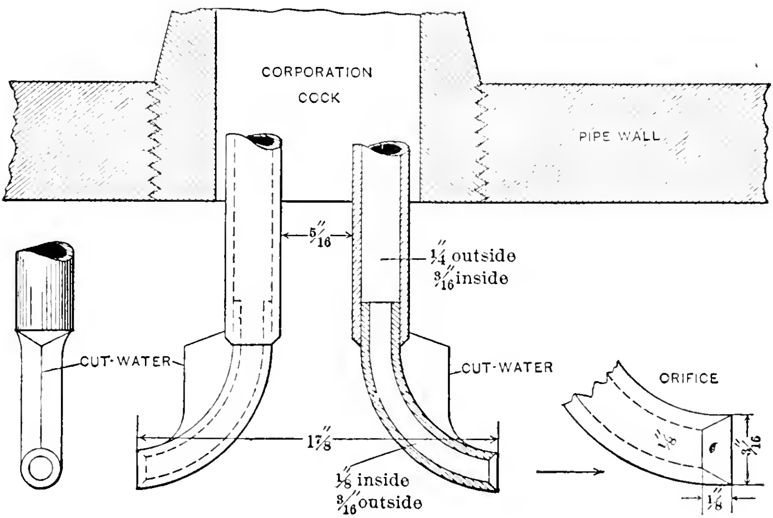


FIG. 1.

within the pipe with a record of the U-tube deflections, the latter, of necessity, being half deflections, as shown on the U-tube. The instrument has shown itself capable of producing a good continuous record upon ordinary Velox paper. Plate II is a sample of such a record. Notches in the slit through which the light passes on its way to the paper are so located that they produce horizontal rulings upon the record, corresponding to the calibrated deflections taken from the curves (Fig. 2). The combination of static pressure variation with velocity aids in interpreting the cause of any given variations in the flow.

It is first necessary to ascertain, by an operation called a "traverse," the relation between the average velocity in the main and the highest velocity, which is usually at or near the center. This

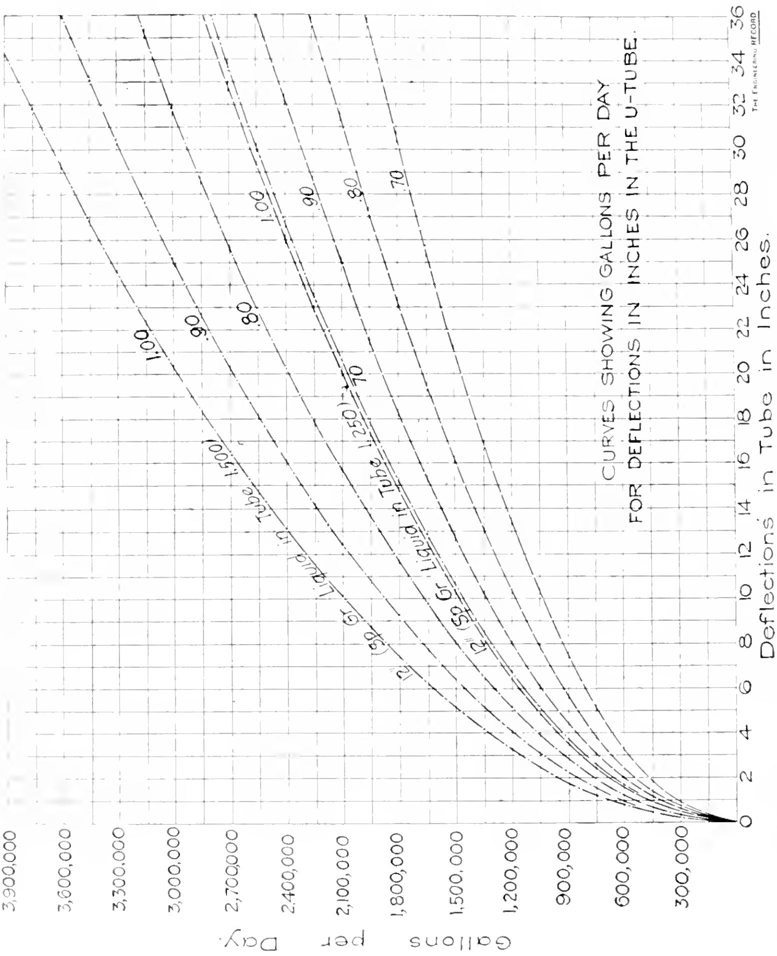


FIG. 2. CURVES SHOWING RELATION BETWEEN DEFLECTION IN U-TUBE AND QUANTITY OF WATER FLOWING.

relation varies considerably, according to the age of the main and the material of which it is made. When this relation — called the coefficient of the pipe — is ascertained, the orifices are

PLATE II.

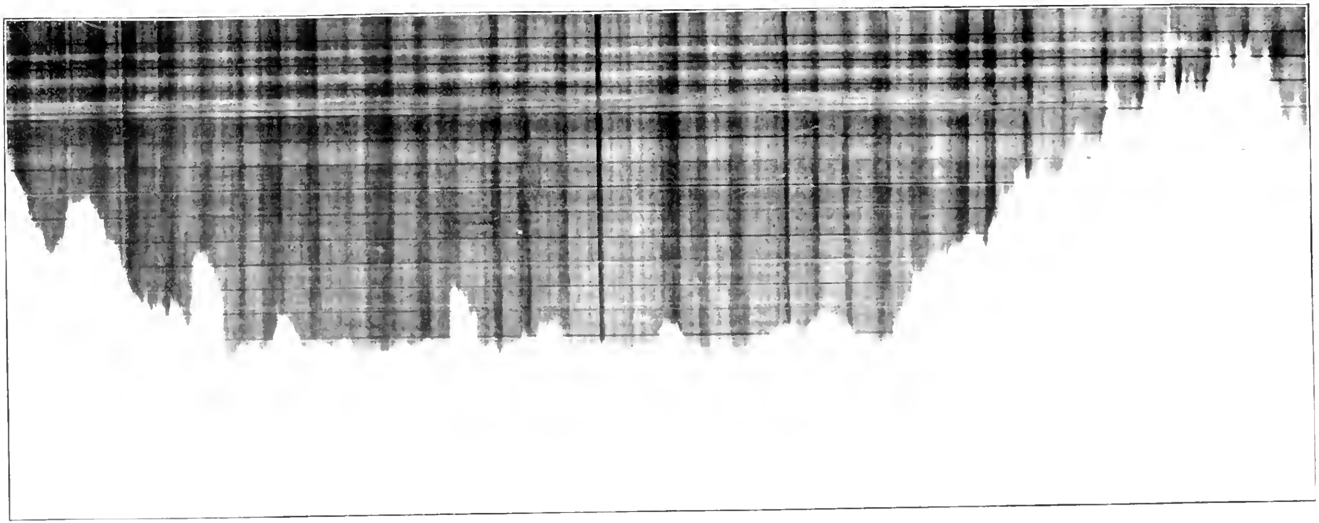
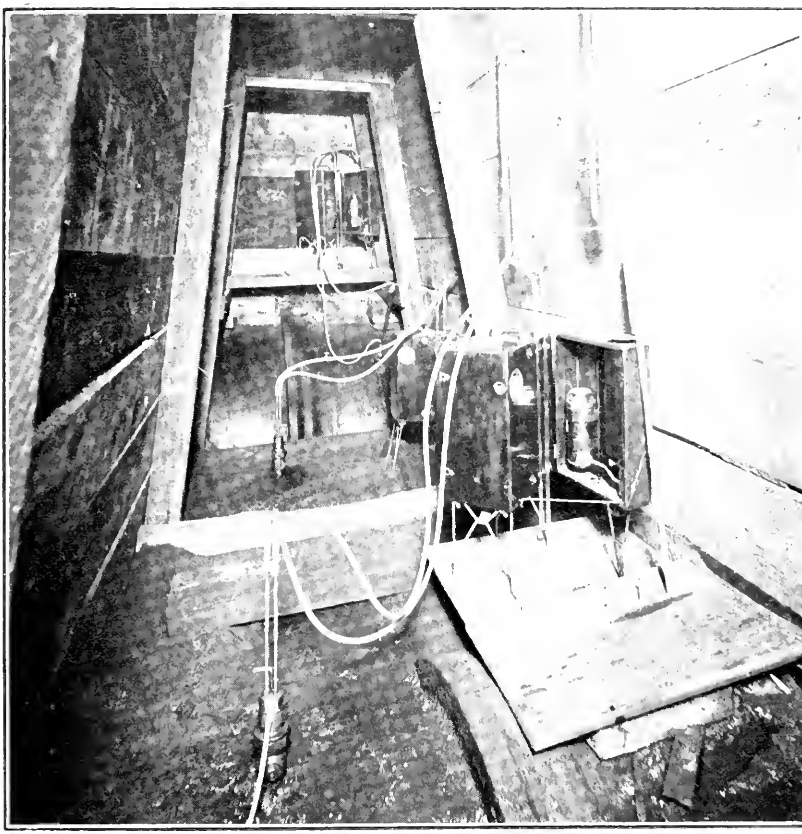


PHOTO-RECORD OF THE CONSUMPTION IN A PURELY RESIDENCE DISTRICT OF COLUMBUS, OHIO. POPULATION OF DISTRICT, 46 000. THE RECORDED PER CAPITA CONSUMPTION AT NIGHT EQUALS 1.6 GALLONS PER HOUR.

PLATE III.



THE PITOMETER IN USE.

then set at the point of greatest velocity and remain there throughout the test.

The greater the velocity in the main, the greater the force with which the water impinges against the up-stream orifice, and it is the function of the metallic tubes, the rubber connections and the glass U-tube to communicate this pressure to the surface of mercury, or other liquid heavier than water, which will thus be depressed in one arm of the U-tube in accordance with this varying pressure. In order to make a permanent record of the movement of this liquid, the photo-recorder photographs the liquid upon a drum, which revolves steadily, thus showing a line on a sheet of paper which can be interpreted into gallons for any minute or hour of the day or night.

The pitometer, when thus used with a photo-recorder, registers automatically all the variations in velocity which take place in a water main. It is the only meter which can be used at will on all sizes of mains. It is portable and may be readily attached to any water main by means of a 1-inch corporation cock. A 1-inch reamer should be run entirely through the corporation and the key before placing it in the main. The location should be in a straight run of pipe, at least 50 feet, if possible, from all disturbing valves, bends, tees, etc. A less distance may be safe if the velocity is below 3 feet per second.

The uses of the pitometer may be classed under three heads, viz., engine tests, district surveys, and street inspections.

Engine Tests. The first work done is usually that of making a test of the pumping engines, or, in case of gravity works, of the reservoir flow. This indicates the deduction which must be made from station logs for slip of pumps or defective formulæ.

This test alone is often found to be one of great significance. Frequent slip-tests are of great utility, and if all works were equipped, it would enable the engineer in charge to make these himself at regular intervals.

District Surveys. The next step is usually that of dividing the area of the entire city into large districts. The flow of water into each of these districts is ascertained by the photo-recorder on a continuous run of several days and nights, including, if

possible, a Sunday. From these records, which show the use for every hour, a comparison is made with the actual requirements of the district as shown by its total metered use and a reasonable allowance for its resident population, and in this way a valuable result is reached. It often happens in such cases that a large area is shown to use but a normal quantity, considering its population, and that the night flow is not greater than it should reasonably be. This fact, once established, makes further work in that district unnecessary. On the other hand, the record may reveal an abnormal flow into a district and an excessive night consumption. This indicates a section which should be subdivided and carefully investigated. Large losses through broken mains and services, and important uses that have not been fully metered and charged for, are readily determined by such a test.

Street Inspections. Taking now the districts which are evidently consuming an excess of water, especially at dead of night, the next step is that of taking records upon short lines of mains by shutting off in their order all the services supplied on the line. This process at once indicates a place where defective service pipes or imperfect fixtures are leaking. After all known services have been shut off there may still remain a flow that indicates loss from imperfect joints, a break in the main, or some unsuspected and unmetered consumer. In old works a frequent cause of leakage is found in decayed service pipes. Forgotten and disused services and mains are fruitful sources of loss. Fire-protection mains are peculiarly subject to losses through unmetered connections, which, for aught any one seems to know, have made themselves. This street inspection brings all such misfortunes to light, and its value can only be adequately understood when the cost of the water which flows away in a constant stream for a year, and year after year, is capitalized.

By using the pitometer street connection, records can be repeated at any given point, thus revealing the changes which take place from one season to another. This adds greatly to the ease with which the use of water throughout the system can be made a matter of certainty to the manager. By locating these street connections on fire-protection mains, inspections can be made from time to time which will prevent an unauthorized use

of water through surreptitious connections. As this method of inspection leaves the main unobstructed at all times, its use is not objectionable from the fire underwriters' standpoint. If one of these street connections to each mile of main is judiciously set, it will be practicable to reach every block of a pipe system so as to determine positively whether any given water gate is shut or open, and also to locate any considerable loss of water through defective mains or services, or to locate the theft of water.

By using the pitometer in a thorough and systematic way in connection with careful inspections of fixtures, any city can know where the water of its system is used and can find every source of loss. It affords a very economical and practical way of measuring the water flowing through any pipe in any street. Its cost and its ease of handling are such that even the smallest water-works plant can afford to use it. It is peculiarly fitted for use by large cities, where every mile of the pipe system can be inspected without interference with the supply of water.

In 1881 and later, a total of 83 Deacon meters were placed on the distribution system of the Boston Water Works in the study of waste. The average cost of their installation complete was about $600 each, making the total cost of installation in the neighborhood of $50 000. It is interesting to note that 500 pitometer street connections could be placed, one to each 3 miles of the 1 500 miles of piping of 4 inches and over supplied by the Metropolitan Water Works in 1905, and 100 complete pitometers with photo-recording apparatus installed, for the same sum of $50 000. By a careful study of the successive points of distribution of the pitometers, this equipment would enable the Board to learn the exact condition, flow, waste, leaks, breaks, etc., at every point in its large distribution system, and such data could be repeated at different periods as often as desired.

The writer installed and directed the operation of a complete pitometer, with photo-recording apparatus, at Athol, Mass., during the fall of 1905, for the purpose of determining the gravity flow through two mechanical filters. During the latter period of its operation, excavations were being made for the permanent installation of a Venturi meter at the same point. The flow by pitometer gagings was testified to at the hearings before a special

commission, before any records had been taken from the Venturi, but when the Venturi records were entered in the later course of the testimony, they were found to agree very closely with the pitometer — as should always be the case when both are installed properly and operated intelligently. The pitometer was used successfully in the famous New York waste investigations of 1902 and 1903, and is in use to-day at Chicago, Philadelphia, Pittsburgh, Havana, Washington, Spokane, Minneapolis, Rochester, Syracuse, Cleveland, Watertown, N. Y., Bridgeport, New London, and other smaller cities and towns.

In preparing the above information to cover the limited time assigned to this paper, I have extracted freely from the text of the literature published by The Pitometer Company.

DISCUSSION.

MR. C. M. SAVILLE (by letter).* I think we are greatly indebted to Mr. Blake for his interesting exposition of the pitometer and its uses in connection with water-waste investigations, especially in cases where a hurried reconnoissance is to be made over a large system.

Regarding the suggestion for installing them on the Metropolitan Water Works, I would state that this system is now equipped with 55 Venturi meters, controlling all of the connections with the 18 separate cities and towns supplied from these works. From these meters an autographic record of the flow during *any* period is available and is filed for future reference. This record requires no expert knowledge of photography or manipulation in development, and the chart can be adjusted and taken off by a laborer of ordinary intelligence.

Besides the autographic record, which gives the rate of flow at any time, the Venturi register also shows on a dial, similar to that on the ordinary house meter, the total quantity in gallons actually passed. This is a great advantage over a chart record giving only rates of flow, as it requires no calculation to reduce it to the quantity actually consumed. The chart records have furnished very interesting and valuable information regarding the use of water for fires, blowing off and flushing water pipes and

* Division Engineer, Metropolitan Water Works, Boston, Mass.

sewers, and the results on small systems of the sudden opening of connections for supplying street-watering carts and locomotive tanks. Besides the above, immediate information is given of gates carelessly opened between high and low service systems, and of breaks in mains and services from which water is running away unnoticed into drains and brooks.

On the Metropolitan system these meters have been used many times to investigate waste, the method being to feed the system under inspection through the meter, noting the time of shutting section gates, cutting off certain portions of the district, and later reading the rates of flow on the meter charts at the time mentioned, the rate of decrease, or quantity used by the cut-out section, is readily obtained.

One step further in this method of waste detection would be to tap ordinary connections on either side of a section gate and lead, say, 2-inch connections into a permanent chamber. Here, by means of flanged connections, a small Venturi meter, say, 2-inch, could be inserted at any time. By closing the main gate between the connections the flow to the district under investigation could be by-passed through the small Venturi and by means of adjustable throat pieces any rate of flow per minute from 1.74 gallons or 0.23 cubic feet to 90 gallons or 12.1 cubic feet could be automatically recorded by a manometer, while street-by-street and house-to-house inspection by closing street gates and curb cocks is being done by the water works department. The great advantages of this method are:

1. Its low cost for installation, the entire first cost (and consequent ownership) being a comparatively small amount.

2. Its portability, one outfit of meter and manometer being readily transported and used in as many testing chambers as is required on the system.

3. Its autographic record, requiring no photographic manipulation, and being ready for inspection at any time without development.

4. No survey of the pipe and determination of a proper coefficient being necessary.

5. Its simplicity of operation, lending itself readily to operation by local departments.

Mr. Blake (*by letter*). Mr. Saville's instructive discussion has been read with much interest. It was not intended to suggest that pitometers should now be installed on the Metropolitan system, but to show what might be accomplished by their use with an investment equal to that made with Deacon meters in 1881 and later. The comparison showed the great advantages of the pitometer in point of information obtainable for a given investment.

In regard to the expert knowledge of photography which Mr. Saville thinks is required, the writer would have endeavored to make this matter, as well as several other details, clearer had time permitted. The sensitized Velox paper can be purchased at any photographic supply store, cut into the exact size desired. It must be placed on the drum in a dark room or corner, and protected from the light until in place on the drum above the clockwork. When the record is completed, which may cover twelve, twenty-four, or forty-eight hours, the Velox paper is removed, and rolled in a small tin case. Tubes of developer and acid hypo for fixing solution can be bought cheaply at almost any stationery store. Fresh water is all that is required in addition, and the simple directions show the process plainly. Photography has become so common with even young boys and girls that it can hardly be said to require expert knowledge as demanded in the development of pitometer diagrams. A laborer of ordinary intelligence can put on and remove the Velox sheets, and, if desired, they can be collected once a day and developed at the office, where, with scarcely an exception, some assistant is found well versed in photography.

In regard to the Venturi dial, referred to by Mr. Saville, which shows at a glance the gallons passing at any moment, a pitometer scale is quickly made from the tables to suit any traverse coefficient and any size of pipe, and this scale, with its zero placed at the zero line of the liquid in the U-tube, enables the observer to note the exact number of gallons passing at any moment. Furthermore, notches in the slit through which the light passes on its way to the paper are so located that they produce horizontal rulings upon the record corresponding to the calibrated deflections, and after being developed, the discharge in gallons

for the given traverse coefficient and pipe size is readily entered for each line of the record, making the record self-reading without calculation or scaling, except for intermediate points.

In the investigation of waste by the pitometer, any main can be tapped anywhere, except at or very near bends, branches, etc., without by-passing the entire supply or any part of it through a neck or other reduced section, and, of course, complete inspections can be made by shutting section gates, curb cocks, etc. Also changes in the rate of flow, due to use of water for fires, blowing off and flushing water pipes and sewers, the sudden opening or closing of gates, breaks in mains and services, etc., are faithfully recorded on the photometric diagram, not at ten-minute intervals, but continuously.

Mr. Saville suggests the use of a 2-inch Venturi meter with adjustable throat pieces in waste detection. He states that to do this would require a tap on each side of a section gate, 2-inch connections, and a permanent chamber.

Compare with this a single 1-inch corporation cock tapped into the main, a simple and inexpensive pitometer street connection placed in position, and the whole surrounded by a piece of 6-inch or 8-inch pipe running up to the surface and having an ordinary cap such as is used for curb cocks. There is no by-passing, no by-pass valves, no permanent chamber large enough for a man to work in. The comparison seems to show that for the particular field of waste detection the pitometer is preëminently fitted above all other types of meter, and is therefore destined to have a very wide use in the future, in view of the fact that every year cities and towns are made to realize that consumption must be minimized and unnecessary waste stopped. The pitometer reveals in part the actual interior condition of the pipe and measures the flow as it actually takes place in the pipe day by day.

The writer has been informed that the cost of installation of the 55 Venturi meters on the Metropolitan system was in the neighborhood of \$90 000. The cost of an equal number of complete pitometers would probably not exceed \$20 000. Making the same comparison as used in reference to the Deacon meters, for an equal investment of \$90 000, 1 500 pitometer street connections could be placed, one on each mile of the 1 500 miles

of piping of 4 inches and over in diameter, supplied by the Metropolitan Water Works in 1905, and 150 complete pitometers installed, or one to each ten miles of piping. Thus continuous records could be taken simultaneously at nearly three times as many points as is possible with the Venturi meters now in use, and then the pitometers could be moved to other 150 points, and so on, until the day and night flow on each mile of the system had been recorded. The great increase in information thus available is obvious; and although it doubtless would not be desirable to go into the matter so minutely on the Metropolitan system, the above figures are intended to show what might be accomplished by the use of pitometers with an investment equal to that made in the case of the 55 Venturi meters.

MR. GEORGE W. BATCHELDER.* We used the pitometer in the fall of 1903 with most satisfatory results. I do not remember having any difficulty with it, and do not think it requires any expert knowledge to operate it.

We found some very startling results on some of our fire pipes, which results were afterwards practically verified by the readings of meters placed on the pipes.

The instrument appeals to us as practical and easy of operation, so much so that we shall undoubtedly order one very shortly.

* Water Commissioner, Worcester, Mass.

WATER SUPPLY, TYPHOID FEVER, DIARRHEAL DISEASES, AND INFANT MORTALITY AT BURLINGTON, VT., 1879 TO 1905, INCLUSIVE.

BY M. N. BAKER, PRESIDENT OF THE BOARD OF HEALTH, MONTCLAIR, N. J., AND ASSOCIATE EDITOR OF "ENGINEERING NEWS."

[*Read March 14, 1906.*]

The water supply of Burlington, Vt., affords an exceptional opportunity to study the relations between water supply and disease, and to extend such studies so that in addition to typhoid fever they will include both diarrheal diseases and infant mortality. This opportunity is due to the fact that Burlington draws its water supply and discharges its sewage alike into Lake Champlain, without purification in either case, and to the further fact that its vital statistics, while not wholly satisfactory, have for a long period of years been superior to those of most cities. The study is rendered doubly interesting and significant because two increases in the distance between the water intake and the main sewage outlet, making a final distance apart of some three miles, as compared with a half mile originally, appear to have failed to protect the water supply from the constantly increasing discharge of sewage into the lake, which latter has been augmented of late by the sewage of other localities than Burlington.

My first acquaintance with the water supply at Burlington was in the fall of 1882, when upon entering the University of Vermont I received the warning customarily given to students, to drink sparingly of the lake water until accustomed to it, lest it should give rise to diarrheal trouble. During and subsequent to my course at the university, I followed with interest the local contentions over the relation between the water supply of the city and typhoid fever, diarrhea, and dysentery, which many believed were unduly prevalent in Burlington.

In common with others who gave attention to the subject, I thought that the $2\frac{1}{4}$-mile extension to the water-works intake

made in 1894, which had long been advocated, would secure to Burlington the purity of its water supply for many years to come. At the annual convention of the New England Water Works Association held at Burlington in September, 1895, I listened with great interest to the paper on the history of the Burlington water works and the account of the construction of the intake extension, by my former classmate at the University of Vermont, Mr. F. H. Crandall, then and until recently superintendent of the Burlington water works. At the same convention I heard with much pleasure and profit the notable paper by Prof. William T. Sedgwick, now president of this Association, "On the Sanitary Condition, Past and Present, of the Water Supply of Burlington, Vt." (See JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. X, pp. 150-183, March, 1896, for both these papers.) After the completion of the intake and the presentation of the two papers just named, with their evidently conclusive testimony on the existing and probable future water supply of Burlington, the controversial aspects of the subject passed out of my mind until the publication in 1905 of Mr. M. O. Leighton's "Preliminary Report on the Pollution of Lake Champlain" (Water Supply and Irrigation Paper No. 21, United States Geological Survey). In this report Mr. Leighton considered at some length the history and character of the water supply of Burlington, and included many analyses of samples of water collected from the lake. On reading this report I was surprised to learn that Mr. Leighton's studies, combined with analyses made by the Vermont State Laboratory of Hygiene, at Burlington, indicated that the water supply of that city was again in a dangerous condition. About this time the Vermont State Board of Health issued an order instructing Burlington to improve the character of its water supply. The city authorities appointed a special committee to investigate and report on the subject. The membership of this committee included Dr. John B. Wheeler, chairman, and Dr. F. E. Clark, secretary, both former health officers of the city, and Mr. F. O. Sinclair, M. Am. Soc. C. E., then recently appointed superintendent of water works. In June, 1905, I was requested by the committee to report on the best means of improving the supply. My report was sub-

mitted in the following August. Its conclusions, in brief, were that the statistics of typhoid fever and diarrheal diseases, together with the analyses of the water supply, indicated that some change in the water supply was necessary, and that in view of the abundant supply afforded by the lake and the fact that the works were designed to draw thereupon, it was advisable to continue the supply from that source and to purify it by means of slow sand filtration. Subsequently the special committee embodied my report in one made by it to the city council. In general, my recommendations were indorsed, with the exception that it was not considered necessary to cover the storage reservoirs on the hill, and that the filter plant should be located at these reservoirs instead of at the lake, as suggested by me. By locating the filters on the hill, the necessity of low-lift pumps would be obviated, and by constructing a new force main from the pumping station to the filters, it would be possible to supply a considerable amount of unfiltered water in the heart of the business district for both fire protection and elevator service. The existing force main, it may be explained, serves as a distributer to branch mains along its course; that is, the system is by pumping through the distributing system to the reservoirs, the latter serving to make up any deficiency and to supply the city at any time when the pumps are closed down. Reference to other features of these reports will be made later on.

In view of the detailed information regarding the Burlington water supply already available in the papers by Professor Sedgwick and Mr. Crandall, as printed in the JOURNAL, and in Mr. Leighton's report, it seems unnecessary to go over the subject in detail. A few facts, however, may be drawn from each one of the papers named. These facts, combined with other information, having been given, I shall address myself to the presentation and discussion of those portions of the vital statistics of Burlington which bear particularly on the subject in hand.

On October 1, 1866, the city of Burlington took possession by purchase of the property of the Burlington Aqueduct Company. This company was then supplying water for domestic purposes only, by gravity, from springs located near a 75 000-gallon underground reservoir. On taking possession of the works, the city

installed a pump having a capacity of 63 000 gallons per day, and began pumping the water from the lake to augment the supply of 5 000 to 15 000 gallons daily, delivered through some 200 service connections. On December 25, 1867, the city began the use of a new water-works system which it had built for drawing water from the lake. The intake was only a short distance from the pumping station, which was located on the lake front. This intake continued in use until the completion, in 1894, of the $2\frac{1}{4}$-mile intake extension already mentioned. One or more sewers seem to have been in use prior to 1867, but there appears to have been no sewerage system until 1875. Up to 1885 the main outlet sewer discharged at the dock line about a half mile south of the water intake. In that year an intercepting sewer appears to have been constructed to convey the sewage to a point farther south, the new outlet being about three fourths of a mile from the water-works intake. Storm overflows, it appears, have continued in use since this extension. The water intake extension of 1894 separated the water intake and outlet sewer by about three miles, but at the same time the outlet sewer, which had previously discharged into quiet water, serving as a settling basin, was extended to the dock line, and since then it has discharged into the open lake. The effect of the basin named was to remove, presumably, a considerable part of the dangerous polluting matter from the sewage before the latter reached the main lake. With the extension of the outlet to the dock line the full volume of sewage was subject to the lake currents, as exercised within the line of the breakwater, which parallels the water front for about a mile. The normal lake current is, of course, to the north, but this current is gentle, and within the bay and breakwater it is not only less pronounced than without, but it is also liable to reversal, at least at the surface, by adverse winds.

The new water intake was composed of 24-inch cast-iron pipe, laid in 75-foot sections, with Falcon ball joints between sections. The 75-foot sections were joined by leading in the usual way, the joints being of the bell-and-spigot type. This jointing was done on shore, and each 75-foot section was tested under hydraulic pressure. The sections were then moved out by scows,

sunk, and the ball-and-socket joints, which, of course, had been applied beforehand, were connected under water by a diver. The Falcon joints are described by Mr. Crandall as follows:

"This joint is made of a ball cast of such diameter, larger than the pipe on which it is to be used, as to admit the desired deflection to be obtained without obstructing the waterway, and a flanged spherical ring of about three-eighths inch greater radius than the ball and of such width that the ball cannot pass through it. These two parts are leaded together and attached to one end and a flanged bell, planed so as to make a tight thimble for the ring which is attached to the other end of a section to be laid.

"The flanged joint is made by a diver with the aid of a thin rubber packing, and after it has been for a short time in our lake water the oxidation which takes place on the planed surface of the ring and thimble makes it entirely watertight. In a case like that of our intake, where there is no current of constant and high velocity to keep open and increase the size of leaks induced by changes of temperature or settlement, it may safely be expected that all small holes will be closed by oxidation."

Mr. Crandall stated in his paper that the bottom of the lake, on which the pipe rests,

"is nearly level, but there are two summits in the distance, and on those summits were placed brass ferrules with two one-eighth-inch holes bored in each ferrule. Before these holes were opened, the water was let on at a pressure of about 20 pounds, and we noted the amount of leakage, and the same was done afterwards, showing the leakage occasioned by the holes. This was done each time that air vents were placed, and when the test was finally made, the pressure which they were subjected to was from 12 to 15 pounds, and the leakage, aside from that through the air vents, was about 100 gallons per hour in the entire length of about 3 miles."

Attention is called to these descriptions of the methods employed in making and testing the lead joints on shore, connecting the sections under water, and testing the intake conduit after it was laid. The question naturally arises whether all the joints made under water rusted to tightness, as Mr. Crandall expected would be the case.

The provision of a gate at each extremity of the intake conduit, that is to say, at the pump well and at the upturned outer

end of the intake, made it possible to retest the whole intake at any time after it was put in use. No reference to such tests has been found by me in the annual reports of the Water Department; and although the first recommendation of my report, dated August 30, 1905, was that such tests be made, none had been undertaken up to March 1, 1906.

It should be noted that the intake conduit was laid in water ranging from some 14 to 50 feet in depth, and terminated in water some 30 feet deep, but with a strainer capped, upturned end, the upper portion of the perforated cap being 14 feet below ordinary low water in the lake. The successive depths at which the intake was laid from the pumping station outward, at approximately equal intervals, were as follows: 12 feet (near the shore), 24, 38, 46, 48, 46, 46, 28, 45, 50, 44, 29, 31 (and 14 at the strainer, at stated above).

Professor Sedgwick's paper contains a number of very interesting extracts from the reports of successive health officers, beginning as early as 1870, calling attention almost without exception to the desirability of extending the old intake at once. The two exceptions were to the effect that the allegations against the character of the city water supply were apparently unfounded. In the year 1870, Professor Sedgwick states, there were 5 deaths in Burlington from dysentery and 3 from diarrhea, and in 1871 there were 10 deaths from dysentery, according to the city reports. These figures certainly emphasize the need, even as early as 1870, for the extension of the intake, which was deferred, as already indicated, until 1894. Professor Sedgwick included in his paper the substance of a report made by him to the city of Burlington in 1892. In that report he reviewed briefly the typhoid statistics of the city for some years previous. The typhoid mortality, together with the deaths from diarrhea and dysentery, he did not consider alarming; nevertheless, the body of the statistical evidence available, combined with the opinions of successive health officers and practicing physicians, and the known fact that sewage was discharged into the lake so near the intake, all pointed, he concluded, to the need of an improved water supply, which it then appeared could best be secured by extending the intake. Such an extension seemed all the more desirable at that time be-

cause Mr. F. P. Stearns, M. Am. Soc. C. E., had just been called in to advise on the abolition of the nuisance caused at low water by the discharge of sewage into the basin at the mouth of the outlet sewer. Quite recently the lake had been unusually low and the exposure of the sludge-covered mud flats in the basin had resulted in an almost intolerable stench. Mr. Stearns advised that the outlet sewer be extended across the basin to the lake front. This, as has already been mentioned, was completed the same year as was the extension of the water intake.

Between the date of his report and of his paper read in 1895, Professor Sedgwick made numerous bacterial analyses of water from the Burlington supply, and took pains to secure the opinion of some of the physicians of Burlington as to the benefits derived from the extension of the water-works intake. The concluding paragraphs of Professor Sedgwick's paper of 1895 are well worthy of quotation here:

"In view of all the evidence at hand — statistical, bacteriological, chemical, and medical — I think we may safely conclude that the sanitary condition of the water supply of Burlington is now most excellent. If, however, in the future, Burlington grows extensively and becomes a much larger city, it will probably become necessary here, as in most large cities, to face once more the question of a pure water supply. Special pains must also be taken to see to it that the intake pipe is kept intact and free from leakage. The unfortunate experiences of Toronto and of Buffalo with broken intake pipes afford ample warnings in this direction.

"This is the first case within my own experience, now somewhat extensive, in which epidemic diarrhea in a mild form has prevailed in a community for many years, having its etiology in the consumption of impure water, as has been proved by its apparent total disappearance on a change in the source of supply. The importance of the case in the history of water-borne diseases is manifest. It was complicated by the fact that typhoid fever, which is usually taken as a measure of the sanitary condition of a community, was here ordinarily by no means excessive, and that its occasional prevalence might easily have been due to some other cause than polluted water. The fact seems to be, however, that it was in truth really due to impure water, inasmuch as since the extension of the intake pipe in 1894, typhoid fever has practically disappeared.

"It would seem fair to conclude, from the moderate occurrence

of typhoid fever, while diarrhea abounded, that germs of the latter disease, more hardy than those of the former, were frequently able to survive a journey from the sewer outfall to the water intake, while those of typhoid fever, if present, usually perished. In future, sanitarians will not be able by the test of typhoid fever alone to show that a water supply is above suspicion. A mild form of diarrhea caused by polluted water may apparently prevail even in the absence of any constant or considerable excess of typhoid fever."

At the conclusion of the first of the paragraphs just quoted, it will be noted that Professor Sedgwick suggested two possible future contingencies which might demand renewed efforts to secure or maintain a pure water supply: (1) A large increase in the population of Burlington, which has scarcely taken place yet, since the population now appears to be only some 25 per cent. more than it was then; and (2) leaks in the long intake pipe, on which possibility there seems to be no specific information available up to the present time. But in some respects even more impressive than these two suggestions are the remarks in the last paragraph of the quotation, on the relation between a polluted water supply and an excessive amount of diarrhea. This summary of a most significant feature of the sanitary history of the Burlington water supply, and particularly the last two sentences of the paragraph, mark a new epoch, as I believe, in the study of the relations between water supply and disease. The impression made upon me by these remarks, taken in connection with my early knowledge of the effect of the Burlington water supply upon new students at the University of Vermont, and my long-time conviction that sewage pollution did cause other intestinal disturbances than typhoid fever, determined me, on taking up the investigation of the Burlington water supply last year, to attempt a more detailed study of both the typhoid and diarrheal mortality of Burlington than had ever been made before. This determination was strengthened after some study of the Burlington typhoid had confirmed the opinion, by no means held by me alone, that much of the disease had been concealed, particularly in earlier years, by reporting deaths that were actually from typhoid fever as some one of the now well-recognized class of diarrheal diseases.

Never was the need of combining the study of vital statistics with that of chemical and bacterial analysis of a public water supply better illustrated than by this Burlington case. The futility of water analyses alone is well put by Mr. Leighton in his paper on the "Pollution of Lake Champlain." After reviewing the sanitary history of the Burlington water supply, Mr. Leighton says:

"One of the most striking features in connection with Burlington pollution brought out by the report of Professor Sedgwick is the apparently enormous power possessed by the lake to assimilate large quantities of contaminating matter and to conceal almost every chemical as well as biological evidence of the presence of pollution."

Mr. Leighton also raised the question whether, in the twelve years since Professor Sedgwick's report, the lake, or rather Burlington Bay, had received so much pollution that it had lost a part of its power of assimilating impurities. He then presented a number of series of analyses of samples of water, collected in the latter part of 1904, the analyses and text being accompanied with charts showing the sampling points. The object of these analyses was to show the range and strength of sewage pollution, both that due to the sewers of Burlington, discharging some three miles to the south of the water intake, and that due to the sewage of Fort Ethan Allen and the village of Winooski, discharged by way of the Winooski River at a point in the lake about three and one-half miles to the north of the intake, Winooski being nearly ten miles, by the river, from the river mouth, and the fort some miles above Winooski. (See discussion of the Winooski River influence, further on.) Much of Mr. Leighton's analytical work was admittedly tentative, some of the results were conflicting, and most of the samples from given points were of a single date only, but the analyses as a whole were instructive and indicated sewage pollution over a large area, including most of the area traversed by the intake conduit and also the area between the intake mouth and the mouth of the Winooski River. Such evidence as was secured rested chiefly on the bacterial rather than the chemical analyses. Most of the counts of total bacteria were not high, all things considered, but the colon bacillus was indi-

cated by many of the samples. Mr. Leighton points out, however, that the coli tests, as made for him at the Vermont State Laboratory of Hygiene, were presumptive, instead of direct, but nevertheless he considered that such of these as gave positive results were undoubted evidence of intestinal bacteria. He held, in conclusion, that the Burlington water supply was undoubtedly polluted by sewage, but that in view of the illusive character of the sewage contamination, so far as analytical determinations are concerned, the record of intestinal diseases in Burlington was the best means of showing "the unfavorable effects of Burlington sewage" on the water supply of the city.

In none of the published studies of the Burlington water supply, and in none of the annual reports of the various health officers of Burlington, do there appear (with one exception) detailed typhoid statistics for a long series of years; and nowhere have there been published detailed statistics of diarrheal mortality. In Professor Sedgwick's paper, already mentioned, the total mortality, typhoid mortality, and percentage of the latter to the former, were given for the years 1870 to 1895, inclusive, and some figures were also given of the typhoid rate per 100 000 for selected years and for groups of years.

Although my first negotiations with the special water supply committee at Burlington, in June, 1905, assumed that both the pollution of the water supply and the necessity for a change of some kind were proven, yet it was finally deemed advisable to show beyond all question, in connection with recommendations for improving the supply, why an improvement, and that immediately, was imperative. I therefore devoted practically all of my spare evenings, for a number of weeks in the summer of 1905 (largely as a labor of love), to an exhaustive study of the Burlington city reports and a compilation and analysis of such of the vital statistics of Burlington as I thought bore upon the subject in hand. I had in my possession the annual reports of the city from the fourth to the fortieth (1868–69 to 1904, inclusive), but inasmuch as the registration of vital statistics did not begin at Burlington until well into the year 1878, I started my figures with the calendar year 1879. Prior to 1878 and well into that year, the vital statistics of Burlington were based upon a canvass

of the city made in January of each year. As may be seen from Professor Sedgwick's paper (page 175), no deaths from typhoid were reported in Burlington for the three years 1873 to 1875, inclusive. In view of the fact that this statistical work of mine, as already stated, was largely a labor of love, and that my report to the special water commission has recently been published minus all the statistical tables (Burlington City Report for 1905), perhaps I need not apologize for presenting the tables complete herewith, with the corresponding figures for the full year 1905 added thereto. I shall also take the liberty of repeating, without quotation marks, considerable portions of my comments on the tables, as made in the appendix to my report, but with some alterations in form and with some additional reflections.

For a number of years, beginning with 1879, the vital statistics of Burlington probably surpassed in completeness and classification those of most cities of its size. There is reason for believing that they are still more than usually complete and well summarized, but it seems a pity that Burlington has not yet adopted the United States census classification of the causes of deaths and thus put its mortality records on a comparative basis with those of other cities. However, most of the essential facts appear to have been given for some years past, rendering a reclassification no serious matter. The footnotes to some of the accompanying tables will show the new classifications and combinations made in connection with deaths from typhoid fever and from diarrheal diseases.

Table No. 1 shows by years, from 1879 to 1905, inclusive, or for twenty-seven years, the midyear populations, total deaths, and deaths per 1 000 population, and also for typhoid fever, diarrheal diseases, and children under five years of age, the number of deaths and the death rates per 100 000 population and the percentage which the deaths from each of these diseases bears to the deaths from all causes. For typhoid fever alone an attempt has been made to include the yearly number of cases, but it was not until 1898 that the cases began to be reported with anything like apparent completeness, the deaths actually equaling or exceeding the cases in the earlier years and the cases not being reported at all in years as recent as 1889 and 1890. As may be

seen, this table shows great fluctuations in all mortality particulars except the death-rate from all causes, which has been fairly constant, and that at a high rate for a city under such favorable natural conditions as are enjoyed at Burlington. Particular attention is called to the fact that although the typhoid deaths for the year 1905 are low, only 15 per 100 000 population, yet the number of reported cases (32) is high, and so are the total deaths and the deaths from diarrheal diseases and of children under five years of age.

Before proceeding further, I wish to explain why I have included deaths from diarrheal diseases in my study and also deaths of children under five years of age. It has been usual, heretofore, to stop short with a consideration of typhoid fever as an index of water pollution and a measure of the effect of such pollution on the public health. The idea has often been expressed, however, that public water supplies unquestionably affect the total death-rate otherwise than through typhoid fever. How to measure that further influence has never yet been determined, so far as I know, but it has been suggested again and again that the large class of diseases known as diarrheal have their many fatalities raised or lowered by the sanitary quality of the water supply.

Unfortunately, mere cases of diarrhea are not reported at Burlington, or, so far as I know, in any other American city. In fact, unless serious, most of them do not come to the attention of a physician. Deaths from diarrhea have not figured high at Burlington, at least not as indicated by the published vital statistics. This may be due to difficult, even if not to faulty, classification and to variations in the classification of reporting physicians from year to year. To have some broader and more stable basis of comparison than is afforded by diarrhea, or even diarrhea and dysentery together, I have included in my Table No. 1 the whole class of diarrheal diseases, as used by the United States Census Bureau. The details on which depend the total for diarrheal diseases shown in Table No. 1 are given in Table No. 2. I have been compelled to add two columns to the list of headings taken from the census, namely, gastro-enteritis and ulceration of the bowels. If I may venture an opinion on such a subject I would sug-

gest that some of the entries under these two heads, under more recent diagnosis, would have swelled the typhoid fever totals, as given in Table No. 1, for the corresponding years. The same is doubtless true of some of the other entries in Table No. 2. In fact, I think this table as a whole is a strong argument for an entire change of base in the study of polluted water supplies and the public health, particularly in the case of the older records. But to hold more specifically to the case of Burlington, I think no impartial competent judge who is or could become familiar with the past disputes at Burlington over the relation between the public water supply and typhoid fever could study the detailed figures of typhoid fever and of diarrheal diseases brought together in this report without being convinced that Burlington has had far more typhoid fever than was ever reported as such, and that there was far more relation between the water supply and diarrheal diseases than has generally been supposed.

The cholera infantum column (Table No. 2) may be consulted with possible profit in connection with both the total deaths from diarrhea and the infant mortality (the latter given in Table No. 1). Some may be inclined to exclude cholera infantum from diarrheal diseases as related to public water supplies, and others to connect many of the cases with impure water. The figures will be interesting to either school of opinion.

The high infant (persons under five) mortality, whether or not attributed in part to the water supply, certainly demands attention, particularly as it shows comparatively little improvement of late.

If it be assumed, as I have for some years past, that a persistent typhoid death-rate of 20 or more per 100 000 population is a reflection on a public water supply, it will be seen from Table No. 1 that the Burlington supply has been subject to condemnation through the greater part of the twenty-seven years covered by the table, with no allowances whatever for the deficiencies in the statistics. The rate has ranged from 6 to 79 per 100 000 and in sixteen of the twenty-seven years has exceeded 27 per 100 000.

In his report to the city of Burlington, made in 1892, Professor Sedgwick referred to an average typhoid rate of 35.7 per 100 000 for a term of years as not high, compared with other cities having

water supplies of good reputation. For that date, and coming at about the time of the notable studies of typhoid fever and water supply at Chicago, Philadelphia, and elsewhere, made by Professor Sedgwick and Mr. Allen Hazen, perhaps an average typhoid death-rate of 35 per 100 000 might not be considered excessive, but I think few persons to-day will fail to agree that so high a rate is a cause for deep concern, particularly if it is suspected that all typhoid deaths are not reported as such, and if it is found that diarrheal and infantile mortalities are high. In no less than 8 of the 27 years between 1879 and 1905, inclusive, was the typhoid death-rate at Burlington above 35 per 100 000, while for these eight years the combined mortality from typhoid fever, diarrhea, and infantile diseases ranged from 46 to 68 per cent. of the deaths from all causes. For convenience of comparison I have brought together in Table 2-A the deaths per 100 000 from all causes and from the three causes named, for the eight years in question; and to emphasize the bad general showing of 1905, notwithstanding its low typhoid mortality of 15 per 100 000, I have added the corresponding figures for that year.

Having examined the yearly figures and their vagaries in some detail, it may lessen the resulting confusion if we smooth out the extremes by considering averages for larger periods. In order to get equal periods for comparison, and also to put by itself the year in which was made the 2¼-mile extension of the water intake, the averages have been cast in the three five-year groups preceding and two similar groups following the year 1894. For our purposes the most significant columns in Table No. 3 are those relating to typhoid fever. The deaths per 100 000 from this disease rose from 27 for the five years ending with 1883 to 42 for the next five years and 44 for the years 1889–93, inclusive. The new intake was put in use some time in August, 1894, and for that calendar year the rate fell to 12. In 1895 (Table No. 1) it dropped to 6 per 100 000, but for the five years ending with 1899 it was 16. During the period 1900–4 the rate rose to an average of 25, or nearly equal to the rate for 1879–83. In 1905 it fell to 15, but, as already stated, the total number of typhoid cases and the other statistics in Table No. 1 are far from reassuring.

The diarrheal diseases, if we take both the deaths per 100 000

and the percentages of deaths from all causes into account, show an increase before and a decrease upon and after the intake extension. Deaths under five years increased in the second five-year period, dropped in the third period and fell still further in 1894; since 1894 they have risen and fallen, successively, standing for 1900–4 quite near the rate figures for 1889–93. For 1905 the mortality from diarrheal diseases was higher than it had been since 1897.

By way of comparison, it may be noted that for the registration cities of the United States in the year 1900, according to the Twelfth United States Census, the diarrheal diseases gave an average of 156.7 deaths per 100 000; the range was from 191.7 for Rhode Island to 117.6 for Michigan cities. The corresponding rural rates were 97.2 for all the registration states; 172 for Rhode Island and 65.6 for Vermont. At Burlington the diarrheal death-rate in 1900 was 182; in 1904, 168; and in 1905 it rose to 232.

So many other factors than water supply enter into both the diarrheal and the under-five-year rates, and particularly into the latter, that undue weight should not be given those rates, but on the whole there is reason for congratulation in their general continued downward tendency and also in the like progress of the general mortality or deaths from all causes. But these several declines make all the more striking the recent steady increase in the typhoid deaths per 100 000. Turning from the five-year periods back to the yearly figures, we find that the typhoid death-rate per 100 000 of 36 in 1904 and of 38 in 1900 have not been exceeded in any single year since the rates of 63 and 45 in 1893 and 1892, respectively.

It is only fair to the water supply to say that milk, oysters, and some other foods liable to sewage pollution may spread typhoid; and that the common house fly is now believed to be a means of infecting food, in sections where privies exist and are accessible to flies. It should also be noted that with populations no larger and typhoid deaths no more numerous than found in Burlington, a slight addition to or decrease in the number of deaths from typhoid makes large variations in yearly rates and in percentages of typhoid to total deaths. Contaminated milk from some dairy or a shipment to Burlington of contaminated

oysters might not cause an epidemic of such magnitude as to lead to a discovery of the real cause of the trouble, but by adding five typhoid deaths to the list might greatly increase the typhoid death-rate for a given year. Another possible factor in the typhoid fluctuations may be patients from outside Burlington admitted to the Mary Fletcher Hospital. It may be noted here that the hospital sewage for some years was discharged into the Winooski River, but about 1892 it was diverted into the lake, thus possibly intensifying the danger of typhoid infection from the water supply. The mention of the hospital also suggests two other institutions which in times past, and I presume at the present time, add an element to the population which may have a marked effect on the returns of deaths from both diarrheal diseases and children under five years of age. I refer to the two children's homes in the city, which at times have added materially to the infant population by receiving children from other parts of Vermont, and therefore may explain, in part, the high infant and diarrheal disease mortality. It is not probable that milk and other food infection combined with the hospital and the institutions for children would fully account for the unsatisfactory typhoid and other vital statistics, though possibly they would lessen somewhat the reflections cast on the water supply.

Unfortunately, the annual reports of the various health officers of Burlington throw no light upon any of the questions raised in the last few paragraphs. They show no investigation whatever of individual cases of and deaths from typhoid fever for the purpose of tracing and removing the source of infection. They give evidence of much concern regarding the public water supply, but of no attempt to settle its actual or assumed connection with typhoid fever, further than through water analyses. I am the more surprised at this because of the evident care and thought given to some phases of health work in Burlington during the past thirty-five years.

The lack or apparent lack of all evidence of the class just named seems to force us back upon deductions already drawn from the data thus far presented, and upon some further details of the same general character, namely, the monthly distribution of deaths from typhoid fever and some digests of water analyses.

Table No. 4 shows the monthly distribution of typhoid deaths from 1879 to 1905, inclusive. The total typhoid deaths for each month during the entire period are also given, and have been rearranged from greatest to least in one of the footnotes to the table. The combined Februarys have 19 of the 120 deaths occurring during the twenty-seven years, and the combined January-March quarters have 44 of the 120 deaths. The lowest combined quarterly showing is 19 typhoid deaths for April–June. The indications are that the ice-covering of the lake is conducive to a high typhoid death-rate. Unfortunately, the returns of cases are too incomplete, particularly in the earlier years, to be of much value.

A study of the analyses made at the State Laboratory of Hygiene, and published in the yearly report of the Water Department, indicates that since 1899, when analyses were begun, the water has frequently been of a decidedly suspicious character. Table No. 5 presents averages of some of the leading features of these analyses. The chemical figures for 1899 and 1900 are notably higher and the bacterial figures decidedly lower than those for later years, except that the total bacterial counts for 1905 averaged the lowest of those for any year shown in the table. Altogether the analyses show variations not easily explained, particularly when taken in conjunction with the vital statistics. On the face of the figures the average analytical results have improved or remained about stationary, save for a slight increase in total bacteria up to and including 1904, a marked fall (to 172 per cubic centimeter) in 1905, and also a recent increase in the relative number of samples showing *B. coli communis*, or the organism common to sewage.

A much more extended series of *B. coli* determinations than those published in the annual reports was concluded at the State Laboratory of Hygiene in January, 1905. A summary of these daily examinations is given herewith, as Table No. 6. It will be seen that of 337 daily samples no less than 147, or 44 per cent., showed *B. coli* present; also that the percentages by months ranged from 60 in December and 57 in January to 25 in July. Judged by generally accepted standards, these daily coli tests afford the most direct and damaging of all the recent testimony against the water supply.

When the intake was extended it was supposed that danger from sewage contamination was removed for many years to come. To account for its so speedy recurrence is not easy, in view of all the circumstances thus far presented, unless one accepts either one or the other of two possibilities: increase in volume of sewage resulting in a wider range of sewage influence, or else leaks in the intake.

As to the volume of sewage now reaching the lake and the probability of its being carried to the mouth of the intake, the following is interesting, even though not conclusive, so far as actual effects are concerned: The sewer outfall is about three miles from the intake. Mr. Leighton's studies led him to conclude that the sewage influences are widely extended and sometimes reach the intake. He gave no little weight to the pollution of the lake at the intake by the sewage brought down in the Winooski River. Unquestionably this is a possible source of danger, but it appears to be far more remote than the danger from the sewage which Burlington discharges directly into the lake. This is evident on considering that from the intake to the mouth of the Winooski is $3\frac{1}{2}$ miles; from the mouth of the river to the poor-farm, 25 000 feet, and to the falls of the Winooski 25 000 feet more. For these distances I am indebted to Mr. F. O. Sinclair, superintendent of water works at Burlington, who also informs me that a small amount of crude sewage is discharged into the river from the poor-farm buildings; that a small part of the population of Burlington is served by a sewer which discharges into the river below the falls; and that Winooski is well provided with sewers, all of which discharge at or near the Falls. Winooski had a population of 3 659 in 1900. Above Winooski, Fort Ethan Allen, I am informed, discharges the sewage of 1 000 or more men into the river, and above that there can be no large amount of sewage pollution until Montpelier is reached, and the direct pollution there, I should suppose, is not large.

According to Mr. Leighton's paper, the Winooski River has a total drainage area of 395 square miles. As nearly all the sewage reaches the river at and above Winooski, it will be seen that before reaching the intake it must pass nearly ten miles through a relatively large, sluggish, and tortuous stream, and then $3\frac{1}{2}$ miles

across the lake, or more than 13 miles in all. Sedimentation and other natural causes in the river and the same factors in the lake, generally acting in the latter case over a wide area and assisted by a still greater dilution, must reduce to a very low figure the usual number of sewage bacteria reaching the intake by way of the river. Among these it is probable, though not certain, that the typhoid bacillus would seldom be found, as water is far from being its natural habitat and it is less hardy in water than *B. coli* and other forms.

The poor-farm sewage stands much more chance than does any other conveyed by the river of reaching the intake in a dangerous condition, since it is so much nearer. Perhaps more serious still, though of this I have little information, is the rendering works on or near the lake shore opposite the intake. Dejecta from cases of typhoid fever at either the poor-farm or the rendering works might be cause for uneasiness if they were allowed to get into the river or lake without thorough disinfection. The populations involved at these points, however, are small.

Reverting now to the sewage of Burlington, as discharged directly into the lake, some idea of what this amounts to can be gained from Table No. 7, which shows by five-year intervals the lengths of all sewers within the city as compared with the mileage of streets and of water mains. It was not until 1895 that a third of the street mileage was provided with sewers, and at the close of 1905 only half of the street mileage had sewers. The water mains have always covered a much larger percentage of the street lengths than have the sewers. Since 1895 the sewer mileage has increased by half, and presumably a far larger percentage of the population is sewered than is indicated by the relation between sewer and street mileage. Lack of sewer connection records in early years makes a direct comparison of sewer and water connections impossible. All the indications are that the percentage of the total population connected with the sewers has increased much faster of late than the total population itself, and that this will be the rule for some years to come. This fact may have no little bearing upon the apparently more rapid increase of pollution of the lake by sewage than was expected when the intake was extended.

Obviously the Burlington records ought to show how many and just what houses are connected with the sewers. Such knowledge is essential to modern health-protective work. A more vital lack in the health-protective equipment of Burlington is the absence of a milk ordinance, combined with dairy inspections, dairy and milk dealer licenses, and other essentials to the full control of the sanitary condition of the milk supply of the city. A milk ordinance of June, 1901, aims to guard milk consumers against tuberculosis, the dissemination of which through milk is a mooted question, and against milk adulteration, which is largely a question of economics rather than sanitation, but leaves the people wholly unguarded against the spread of typhoid fever, scarlet fever, and diphtheria, and the aggravation if not the spread of infantile diarrheal diseases through dirty and germ-infected milk. To this negligence I attribute no small part of the excessive infant and diarrheal diseases mortality, and through these the high general death-rate as well, which latter is excessive for a city of the size, character, and natural advantages of Burlington. It is also probable that some of the typhoid fever has been due to a lack of complete sanitary supervision of the milk supply.

The foregoing paragraph completes the modified excerpts from my Burlington report. It would be highly interesting, and probably instructive, if time permitted, to extend this study in the following particulars: Typhoid records of Winooski village and of Fort Ethan Allen, and the extent of the Winooski sewerage system at various dates; out-of-town patients, total deaths, and typhoid deaths, by years, at the Mary Fletcher Hospital, and possibly the yearly number of inmates and the vital statistics of the two children's homes; and notably, as affecting the total and the infant mortality, the distribution of population of Burlington by age and nativity. It seems probable that the number of children in Burlington is unusually high in proportion to the population, owing to the presence of the two children's homes and the considerable number of French Canadians living in the city. But none or all of these further lines of investigation give promise of removing or to any great extent lessening the suspicion attaching to the water supply of the city. It is of the highest

importance that it be determined at once whether the intake conduit is leaking, and if so whether the water thus admitted is worse than that taken in at the intake mouth. Such a determination involves tests for tightness, provided for by the gates placed at each end of the conduit when it was constructed, and also a fairly extensive series of analytical tests of water taken from points over the intake mouth and at selected points over the whole length of the intake conduit.

Finally, in the light of the statistical and other evidence presented by Professor Sedgwick, Mr. Leighton, the Vermont Laboratory of Hygiene, and myself, it seems that the principle laid down by Professor Sedgwick more than ten years ago, and already once quoted in this paper, is now established beyond all question, namely: "In future, sanitarians will not be able by the test of typhoid fever alone to show that a water supply is above suspicion." The additional test suggested or implied by Professor Sedgwick was the statistics of diarrhea. It does not seem to me, however, that these additional figures alone, in the present state of vital statistics, will be adequate. I do not make so bold as to claim that the whole group of diarrheal diseases, and the infant mortality as well, are essential to the study of the relations between polluted water and disease, but I think the evidence points that way to such an extent as to demand further and broader investigation.

TABLE No. 1. POPULATION, TOTAL AND TYPHOID DEATHS, AND OTHER VITAL STATISTICS OF BURLINGTON, VT., 1879 TO 1905, INCLUSIVE.

	Population.*	Total Deaths.	Deaths per 1 000.	Typhoid Fever. Cases.‡	Typhoid Fever. Deaths. Total	Typhoid Fever. Deaths. Per 100 000.	Typhoid Fever. Deaths. Per cent of all deaths.	Deaths from Diarrheal Diseases. Total.	Deaths from Diarrheal Diseases. Per 100 000 Population.	Deaths from Diarrheal Diseases. Per cent. of all deaths.	Deaths under 5 Years. Total.	Deaths under 5 Years. Per 100 000 Population.	Deaths under 5 Years. Per cent of all deaths.
1879	11 000†	212	19.3	3	2	18	.94	25	227	11.8	91	828	43
1880	11 365	207	18.2	7	3	26	1.45	30	264	14.5	96	845	46
1881	11 690	205	17.5	3	2	17	.98	19	162	9.3	91	779	44
1882	12 010	230	19.2	6	8	67	3.48	20	166	8.7	88	732	38
1883	12 335	224	18.2	1	1	8	.45	25	200	11.2	95	772	43
1884	12 655	218	17.2	20	10	79	4.59	30	237	13.7	87	688	40
1885§	12 980	247	19.0	0	1	8	.40	24	185	8.9	119	914	48
1886	13 300	248	18.6	2	4	30	1.66	29	218	11.8	101	753	41
1887	13 625	270	19.9	10	4	30	1.48	33	243	12.2	118	868	44
1888	13 950	347	24.3	26	9	64	2.60	59	423	17.0	168	1 204	48
1889	14 270	233	16.3	No report	8	56	3.43	35	245	15.0	97	679	42
1890	14 590	288	19.7	..	4	27	1.39	49	336	17.0	135	925	47
1891	14 995	255	17.0	16	4	27	1.57	25	166	9.7	66	447	26
1892	15 400	306	19.2	27	7	45	2.27	56	363	18.3	127	825	41
1893	15 805	284	17.8	30	10	63	3.56	27	171	9.6	93	595	33
1894‖	16 210	290	17.9	4	2	12	.69	35	216	12.1	94	580	32
1895	16 615	291	17.5	15	1	6	.34	21	127	7.2	112	674	38
1896	17 020	360	21.2	6	4	24	1.11	45	265	12.3	153	893	42
1897	17 425	333	19.1	7	2	12	.60	14	254	13.2	123	706	37
1898¶	17 830	283	15.9	32	5	28	1.79	12	68	4.2	83	465	29
1899	18 235	348	19.1	33	2	11	.59	35	192	10.1	111	608	32
1900**	18 640	329	17.7	35	7	38	2.12	34	182	10.3	114	612	35
1901	19 045	326	17.2	22	5	26	1.53	34	178	10.4	123	646	38
1902	19 150	312	16.0	19	2	10	.64	25	128	.79	114	586	37
1903	19 855	379	19.0	29	3	15	.79	30	151	.79	116	584	31
1904	20 260	365	18.0	36	7	36	1.91	34	168	9.3	126	622	35
1905	20 665	434	21.0	32	3	15	.68	48	232	11.1	145	700	34

* Population for intercensal years computed by the United States Census Bureau method; that is, by arithmetic increase between censuses.

† The population decreased about 3 000 from 1870 to 1880; the 1879 population used is arbitrary.

‡ Cases of typhoid cannot be compared with deaths, since the compiler has added to the typhoid deaths given in the annual health reports all deaths reported as bilious, continued, enteric, slow and typho-malarial fever. See footnote to Table 4, Deaths from Typhoid by Months.

§ Main outlet sewer shifted to point one-half mile farther from water intake, making a total distance of about one mile, but understand that storm overflow has been in use at old outlet ever since.

‖ New intake in use "several months" during 1894, apparently beginning in August. Main outlet sewer extended in 1894 to discharge at dock line, instead of into still water, virtually a settling basin, back of dock line.

¶ Late in 1898 a reservoir of nearly 4 000 000 gallons capacity was put in use, and the old reservoir, which was in great need of cleaning, was disconnected. Not stated whether used again before 1900.

** Old reservoir cleaned, repaired, and banks raised; capacity evidently increased from about 2 350 000 to 3 000 000 gallons, making a total capacity of about 7 000 000 gallons, not including high-service tank.

TABLE No. 2. DEATHS FROM DIARRHEAL DISEASES AT BURLINGTON, VT., 1879 TO 1905, INCLUSIVE.

	Cholera Infantum.	Cholera Morbus.	Colitis.	Diarrhea.*	Dysentery.*	Enteritis.	Gastro-Enteritis.	Ulceration Bowels.	Total.
1879	18	..	..	5		2	..	..	25
1880	20	..	..	7		3	.	..	30
1881	12	1	..	2		4	.	..	19
1882	7	3	1 [1]	1		3	2	..	20
1883	8	..	..	5		12		..	25
1884	16	..	..	7		3	1	..	30
1885	13	..	..	..	1	8	2	..	21
1886	19	1	..	..	..	2	6	1	29
1887	15	1	..	..	2	1	8	..	33
1888	32	1	..	..	1	12	12	1	59
1889	13	..	9 [1]	1	..	7	5	..	35
1890	26	..	6 [1]	1	2	7	6	1	49
1891	14	..	3 [1]	..	..	3	3	2	25
1892	37	2	..	3	..	6	7	1	56
1893	15	1	1 [1]	2	1	2	5	.	27
1894	22	2	2 [1]	..	1	4	3	1	35
1895	14	..	1 [1]	2	2	1	1	..	21
1896	28	..	5 [1]	5	2	4	1	..	45
1897	22	2	2 [1]	2	1	8 [2]	7	..	44
1898	3	..		3	1	2	2	1	12
1899	21	1	1 [1]	1	..	8 [2]	3	..	35
1900	20	1	2 [1]	..	..	6	5	..	34
1901	21	1	3 [1]	2	1	3	3	..	34
1902	17	..	1 [1]	..	1	5	1	..	25
1903	17	..	3 [1]	1	..	2	7	..	30
1904	19	..	5 [3]	3	..	3	1	..	34
1905	17	..	1 [1]	..	1	9	17	..	48

* From 1879 to 1884, inclusive, diarrhea and dysentery were not separately reported.

[1] Entero-colitis.

[2] Including one intestinal colic.

Including one entero-colitis.

TABLE No. 2-A. — DEATHS PER 100 000 AT BURLINGTON, VT., FROM ALL CAUSES, TYPHOID FEVER, DIARRHEAL DISEASES AND DEATHS UNDER FIVE YEARS, FOR THOSE YEARS IN WHICH THE TYPHOID DEATH-RATE EXCEEDED 35 PER 100 000.*

	All Causes.	Typhoid Fever.	Diarrheal Diseases.	Under Five Years.	Per Cent. Three Causes are of All Causes.
1882	1 920	67	166	732	50
1884	1 720	79	237	868	58
1888	2 430	64	423	1 204	68
1889	1 630	56	245	679	60
1892	1 920	45	363	825	65
1893	1 780	63	171	595	46
1900	1 770	38	182	612	47
1904	1 800	36	168	622	46
(1905†)	(2 100)	(15†)	(232)	(700)	(46)

* In sixteen of the twenty-seven years from 1879 to 1905, inclusive, the typhoid mortality exceeded 20 per 100 000.

† 1905 inserted for comparison.

TABLE No. 3. — DEATH-RATES FROM ALL CAUSES AND FROM TYPHOID AND OTHER DISEASES BY FIVE-YEAR PERIODS BEFORE AND AFTER EXTENDING BURLINGTON WATER-WORKS INTAKE.

	All Causes per 1 000.	Typhoid.		Diarrheal.		Under 5 Years.	
		Per 100 000.	Per cent. all deaths.	Per 100 000.	Per cent. all deaths.	Per 100 000.	Per cent. all deaths.
1879–83 . .	20.2	27	1.18	204	10.9	789	43
1884–88 . . .	20.0	42	2.14	263	13.1	891	45
1889–93 . . .	18.2	44	2.43	256	14.1	690	38
1894	17.8	12	.69	216	12.1	580	32
1895–99 . .	18.5	16	.86	182	9.8	668	36
1900–04 . .	17.6	25	1.40	161	9.2	609	35
1879–1904	18.4	29	1.58	208	11.2	708	38
1905	21.0	15	.68	232	11.1	700	34

TABLE No. 1. MONTHLY DISTRIBUTION OF TYPHOID* MORTALITY AT BURLINGTON, VT., 1879 TO 1905, INCLUSIVE.

	JANUARY.	FEBRUARY.	MARCH.	APRIL.	MAY.	JUNE.	JULY.	AUGUST.	SEPTEMBER.	OCTOBER.	NOVEMBER.	DECEMBER.	TOTAL.*
1879..	..	..	..	..	1	..	..	..	..	..	..	1	2
1880..	..	1	..	..	1	..	1	..	..	..	..	..	3
1881 .	..	..	..	..	..	..	..	..	1	..	1	..	2
1882..	..	3	2	..	..	..	..	..	..	1	2	..	8
1883..	1	..	..	..	..	..	..	..	..	..	..	..	1
1884..	1	..	..	..	..	2	1	2	..	1	..	..	10
1885..	..	..	..	..	..	1	..	..	..	..	..	..	1 (1)
1886.	..	..	..	..	..	2	..	..	1	1	..	..	4 (2)
1887.	2	..	..	1	..	..	..	..	..	..	..	1	4 (2)
1888..	1	..	..	1	..	1	1	..	3	1	..	1	9 (5)
1889..	1	2	..	1	..	..	..	1	1	1	..	1	8 (2)
1890..	..	1	1	..	..	..	1	..	..	..	..	1	4 (3)
1891..	..	3	..	..	..	..	..	..	..	..	1	..	4
1892..	1	..	1	..	..	..	..	1	..	2	1	1	7 (4)
1893..	1	4	2	..	1	..	..	1	1	..	..	..	10 (2)
1894..	..	1	..	..	..	..	..	1	..	..	..	..	2 (1)
1895..	..	..	..	..	..	..	1	..	..	..	..	..	1
1896..	..	1	..	..	..	1	1	1	..	..	..	..	4 (3)
1897..	..	..	..	..	..	1	1	..	..	..	..	..	2 (1)
1898..	1	1	1	..	..	..	..	..	1	1	..	..	5 (1)
1899..	..	..	1	..	..	..	..	1	..	..	..	..	2 (1)
1900..	2	2	..	..	..	..	..	..	1	1	..	1	7
1901..	1	..	2	1	..	..	..	..	..	..	1	..	5 (1)
1902..	..	..	..	1	..	..	..	..	..	..	..	1	2
1903..	..	..	..	..	1	1	..	1	..	..	..	..	3
1904..	..	..	1	..	..	1	2	..	1	1	1	..	7
1905..	1	..	1	..	..	..	..	..	..	..	..	1	3
Total	13	19	12	5	4	10	12	9	10	10	7	9	120 (29)

* Included in the typhoid mortality as here given are, for the whole period, 29 cases classed in the city reports as bilious and other fevers. The totals by years are given in parentheses at the right in the last column; in detail they are as follows:

1885. — 1 typho-malarial fever in June.
1886. — 1 bilious fever in June; 1 slow fever in September.
1887. — 1 typho-malarial in May and 1 in December.
1888. — 1 continued fever in April, 1 in July, 2 in September, 1 in October.
1889. — 1 continued in February; 1 enteric fever in April.
1890. — 1 continued in July; 1 typho-malarial in March and 1 in December.
1892. — 1 continued in January and 1 in December; 1 enteric in October; 1 typho-malarial in August.
1893. — 1 bilious in February; 1 continued in March.
1894. — 1 bilious in August.
1896. — 1 continued in August; 1 typho-malarial in February and 1 in June.
1897. — 1 bilious in June.
1898. — 1 bilious in October.
1899. — 1 bilious in August.
1901. — 1 bilious in January.

1885 to 1901: Continuous, 11; typho-malarial, 8; bilious, 7; enteric, 2; slow, 1.

The deaths classed as typhoid in the above table have been rearranged by months from highest to lowest, as follows: February, 19; January, 13; July, 12; March, 12; June, 10; September, 10; October, 10; August, 9; December, 9; November, 7; April, 5; May, 4; total, 120. The monthly mass average is 10.

By quarterly periods the grouping, from highest to lowest, is: January–March, 44; July–September, 31; October–December, 26; April–June, 19; total, 120.

TABLE No. 5. — BURLINGTON WATER ANALYSES AVERAGED BY YEARS.

(Chemical results in parts per 1 000 000; bacterial in 1 c. c.)

	Number of Samples.	Bacteria.		Chlorine.	Ammonia.	
		Total.	Coli Present.		Free.	Albuminoid.
1899	27	268	Not reported	1.4	.031	.141
1900	38	529	Not reported	2.3	.039	.139
1901	24	1 293	7 of 24	.9	.021	.134
1902	66	617	13 of 65	1.1	.014	.115
1903	49	641	8 of 49	1.1	.011	.113
1904	50	782	13 of 49	1.0	.012	.114
1905	49	172	12 of 49	1.1	.014	.121

The nitrates and nitrites were first reported in 1903. The nitrates have been as follows, in parts per million: 1903, .190; 1904, .180; 1905, .187. No nitrites were found during these three years.

The total solids for 39 samples collected during 1905 ranged from 95 parts per million on October 11 (the last sample for the year), with a loss on ignition of 37, to 58.5 parts on May 5, with a loss on ignition of 14. The maximum figure given was abnormal, 75 having been exceeded only five times.

The chlorine for the least polluted portions of Lake Champlain does not seem to have been determined. Water Supply and Irrigation Paper No. 144 (United States Geological Survey) shows the lake lying between Isochlors 0.3 and 0.4 (parts per million), but the normal chlorines of waters in towns near the lake, in the vicinity of Burlington, average about 0.5. The range of chlorine found in the samples included in the above table has been from 0.4 to 3.4. By years this range has been: 1899, 0.6 to 2.0; 1900, 1.6 to 3.4; 1901, 0.4 to 1.4; 1902, 0.8 to 1.5; 1903, 0.9 to 1.4; 1904, 0.8 to 1.3; 1905, 0.9 to 1.3. The 3.4 figure, like a number of others for 1900, was for a sample drawn from one of the reservoirs.

See Professor Sedgwick's paper (JOURNAL OF NEW ENGLAND WATER WORKS ASSOCIATION, Vol. X, p. 174) for 28 analyses, mostly of samples from various points in the lake, made from 1882 to 1889, inclusive.

TABLE No. 6. B. COLI COMMUNIS IN DAILY SAMPLES OF WATER FROM THE BURLINGTON WATER SUPPLY, FEBRUARY, 1904, TO JANUARY, 1905, INCLUSIVE.

(Examinations of 1 cc. of water made at the Vermont State Laboratory of Hygiene. B. H. Stone, M.D., Director and Bacteriologist; P. S. Carpenter, Assistant Bacteriologist.)

Month 1904-5	Number of Daily Samples.	Per Cent. of Samples Positive.	Month	Percentages Rearranged, Greatest to Least
February	29	34	December	60
March	31	45	January	57
April	30	36	October	53
May	29	51	May	51
June	28	51	June	51
July	28	25	March	45
August	31	31	April	36
September	16*	31	February	34
October	31	53	November	33
November	30	33	August	31
December	28	60	September	31
January	26	57	July	25
Year	337	44†	Year	44†

* Vacation taken this month.
† Percentage for year based on totals for the year and not merely an average of the monthly percentages; that is, of the 337 samples examined, 147, or 44 per cent., gave positive results.

TABLE No. 7. — LENGTHS IN MILES OF STREETS, SEWERS, WATER MAINS AND ALSO POPULATIONS AND WATER CONSUMPTION, BURLINGTON, VT., AT STATED INTERVALS.

	Length in Miles of			Population.	Average Daily Water Consumption, Gals.	
	Streets.	Sewers.	Water Mains.		Total.	Per Capita.
1880	(50*)	6.14	(20*)	11 365	600 000	53
1885	...	8.54	28.7‡	12 980	621 812	48
1890	53.0	14.07	30.4‡	14 590	756 401	52
1895	54.9	18.76	35.7‡	16 615	888 083	53
1900	55.5	23.91	38.0‡	18 640	857 250	46
1904	56.6	27.50	40.0‡	20 260	987 158	49
1905	56.9†	28.20	40.0‡	20 665	1 056 008	51

* In 1882; not reported in 1880.
† Paved and macadamized, 22.8 miles; graveled, 17.1 miles.
‡ Not including pipe under 4 inches in diameter, which was 5.8 miles in 1885 and 4.8 in 1905.

The present water works were put in operation on December 25, 1867. Mention of the "present sewer" was made in the annual report for the year ending February 1, 1868.

An unusually high percentage of the total population has been supplied with water for many years, according to the annual reports of the water department. As early as 1885 it was estimated by the water department that all but 700 of the population was supplied with city water; in 1905 the unsupplied population was likewise given as only 400. The number of taps or services at the close of 1905 was 3 634, or over 1 per 6 of estimated population; at the same time there were 2 867 meters in use, or 79 per cent. of the total number of taps.

DISCUSSION.

MR. ROBERT S. WESTON.* *Mr. President and Gentlemen of the Association,*— The speaker had the good fortune to look over Mr. Baker's paper in advance. It certainly is a piece of very serious and very careful work. Last night some here enjoyed the privilege of listening to Mr. Baker's after-dinner speech at the annual dinner of the Boston Society of Civil Engineers, in which he took occasion to plead for a broader training for engineers and a more thorough study of engineering problems, especially of sanitary engineering problems, saying that these questions should be studied statistically and not *a priori*.

Such suggestions are very timely, especially when one considers that progress in sanitary science must be based upon vital statistics and that vital statistics are often grossly inaccurate. One has heard of the scholar in politics and the scholar in art; in this paper Mr. Baker expresses the life of the scholar in sanitary science.

In looking over this paper it is especially interesting to note how many more infants there are who die from diarrheal diseases than there are people who suffer death from typhoid fever. The ratio is something like 20 to 1. If these other diarrheal diseases were statistically treated, so that they could be given engineering notice, they would certainly be a worthy subject for frequent discussion in connection with the purity of our water supplies. Health officers frequently say: "Why do engineers always harp upon the typhoid fever death-rate?" And engineers reply: "That is the only group of vital statistics which we can treat as a reality, as a basis for any definite engineering work and expenditure of money." It is certainly very gratifying to read Mr. Baker's scholarly research into the vital statistics and his attempt to solidify the basis for the design and construction, operation, and protection of water supplies.

In this connection it is quite interesting to remember Mr. Hazen's remarks at the International Engineering Congress at St. Louis, when he said that the experience in Albany and in several other cities which he had studied, was that for every reduction of 1 per 100 000 in the typhoid fever death-rate, there

* Sanitary Expert, Boston, Mass.

seemed to be a corresponding reduction of 3 or 4 in the general death-rate. That, if true, certainly would be in confirmation of Mr. Baker's paper.

Two things are quite noticeable at Burlington. *First*, there is a rather uniform distribution of typhoid fever throughout the year, while in many other cities typhoid fever seems to reach its height in the fall. This would point to the absence of what one calls vacation typhoid, and to the existence of typhoid due to local causes. *Second*, the water, even though polluted, is of agreeable appearance, so that the whole community partakes of it and does not, as they do in many other cities, resort to spring and well waters of doubtful history. The problem at Burlington is uncomplicated by such side issues as these.

There are two fallacies in regard to the public health, which, in the speaker's opinion, would be exposed by the public health statistics; namely, what for lack of better terms may be termed the hospital fallacy and the prosperity fallacy. One frequently hears people say, as is written in Mr. Baker's paper with a question mark: "Our city has a higher typhoid fever death-rate in comparison with other cities because we have a hospital in our city; because this hospital draws upon the surrounding country for patients, and because the deaths of these out-of-town patients are included in the statistics." In opposition to this idea one should remember that many people go away from home and die of typhoid fever. One should also remember that every large center of population has a hospital, and naturally every large center of population draws upon the surrounding country for the support of that hospital. Even in suburban towns and cities there are hospitals,— Waltham, Newton, Brockton, Fall River, Taunton, Lowell, Lawrence, all have hospitals, — and in comparing statistics we are comparing the statistics of cities in all of which there are hospitals. Therefore it does not seem to the speaker that the health officer is justified, when he speaks about the typhoid fever death-rate in a city, in excusing lack of sanitary excellence because of the presence of a hospital, unless all the figures are given.

Then there is another fallacy, which may be called the prosperity fallacy, which is this: People say, "Our community is a

very prosperous community, a rich community, and every summer a large number of people go away on vacations, and when they come home they bring typhoid with them. This typhoid fever is not due to conditions in our city, but it is due to the conditions of the summer vacation." There is a great deal of truth in this statement, of course, but the speaker does not think it explains everything by any means (for example, why the wealthy cities frequently have low typhoid), and urges that in studying public health questions the statistical method be used,— but not the statistical method which Dr. Carroll D. Wright exemplifies when he says, "Statistics do not lie, but statisticians sometimes do."

It is a great pleasure to praise Mr. Baker's work and his paper, both for their scientific spirit and their spirit of public service.

Prof. C.-E. A. Winslow.* I have listened with very great pleasure to Mr. Baker's paper, not only for the results which have been obtained, but also as a study in method to be pursued. This is one of those cases where the damage was of the kind that could not be detected and proved by any gross methods. It needed the careful use of statistics and the careful analyses of bacteriological and chemical data to prove it; but it has been proven here, I think, without a shadow of a doubt. Of course statistics are difficult things to handle. In the first place, in this country there are only a comparatively few cities and towns that have good vital statistics; and in the second place, statistics require expert skill and care in handling after they are collected. When, as in this case, you have statistics which have been well collected, and which are ably analyzed, you are on safe ground. One table which Mr. Baker has been good enough to let me look over shows the typhoid deaths by months for a period of years, and I think an inspection of that table alone would be enough to convince any one familiar with typhoid fever that most of the typhoid in Burlington is due to the water supply. In the first place, if milk epidemics were important, the typhoid deaths would be grouped together, a considerable number in a single month, because a milk epidemic almost always effects a considerable number of people at the same time. That is not the case here. The deaths occur two or three at a time only, and there are no

* Massachusetts Institute of Technology, Boston, Mass.

large epidemics. In the second place, the point to which Mr. Weston alluded is not significant, the typhoid deaths being rather evenly distributed over the year, showing even, as Mr. Weston did not state, a slight concentration in the winter and in the early spring.

Now, as Professor Sedgwick has pointed out at a previous meeting of this association, there is a clear distinction between the distribution of typhoid fever by seasons, when it is due to water and when it is not. When typhoid fever is due to causes other than water it has a regular seasonal curve. The typhoid germ is quite susceptible to the temperature, and in cities not having a polluted water supply the disease increases in the autumn, reaching its height in September and October. That is almost an invariable rule, as has been shown by the study of statistics all over the globe. On the other hand, where you have a polluted water supply, typhoid deaths are most apt to occur in the winter, not in midwinter, but at the beginning of the winter when there are heavy rains, and at the end of winter when the thaws come, because those are the times of flood when most polluting material is washed into the water supply. The figures for Burlington show exactly that distribution, and there can be no doubt that the typhoid deaths are due mainly to the water supply.

Again, I think this paper furnishes very valuable testimony as to the importance of bacteriological analyses. The commonly accepted standard is that water which is good to drink should not give a positive test for the colon bacillus in one cubic centimeter certainly not over 50 per cent. of the time. We have lacked data to enable us to fix the standard very closely, but that has been considered a conservative estimate. This paper suggests that perhaps that estimate is a little too high. The analyses in Burlington, where there was a slight pollution, and only a slight pollution, when compared with the water supplies of Philadelphia and Pittsburg, and many other cities, show the colon bacillus in about 40 per cent. of the samples, I think. This shows that we certainly have not been too stringent in insisting upon the 50 per cent. limit, and it suggests that we should probably insist on still greater purity.

There is just one other point I should like to say a word about.

and that is the very important question of the deaths of young children, to which Mr. Baker has alluded. Very few people who have not studied vital statistics realize the importance of this factor in the death-rate, or comprehend that in some communities from 30 to 40 per cent. of the total deaths occur under five years of age. That is the case in many of our large cities, and it is the case in Burlington. It means that perhaps a fifth or two fifths of the children born are swept out of existence before they are five years of age. I do not think that any large part of this death-rate can be attributed to water. In the first place, the deaths are largely of children under one year; and it has been shown by extensive studies in Germany and elsewhere that for the most part this death-rate is due to milk, and to cow's milk, and to rotten cow's milk, — that is, it is due to a poisoning from the putrefaction of cow's milk before the children are fed upon it. But whatever it is due to, it certainly behooves every one to see that the matter is properly studied.

I believe that a great deal can be gained by inciting, as Mr. Baker has apparently wished to do, boards of water-works officials to watch health boards. Health boards already exercise a pretty close supervision over water-works officials, but I think the rule should work the other way, too. It seems to me that every public-spirited citizen, and certainly every water-works official, should study the vital statistics in his own town and find out if there is an excessive death-rate among children. If water is not the cause, he should get after the health board, the proper officials, the people who should supervise the milk supply, and other sanitary dangers, and have them see to it that conditions are remedied.

B. H. Stone, M.D.* It is with much hesitation that I venture to discuss a paper which I have not had the opportunity of hearing, and probably some things which I say would remain unsaid if that opportunity had been mine. I am, however, fairly familiar with Mr. Baker's views of the Burlington water question as expressed in his report prepared for the Special Water Committee appointed to consider the question of a new supply. With most of the views expressed in that report I am in accord. There are a few features of the situation which Mr. Baker passes over as of little importance.

* Laboratory of Hygiene, Burlington, Vt.

to which we at the Laboratory of Hygiene are inclined to give more weight. Mr. Baker suggests that the discussion be along the following lines:

1. Leakage of intake pipes and analytical means of detecting it.

2. Dangers from the sewage of Burlington as compared with that of Winooski and Fort Ethan Allen.

3. Typhoid records at Winooski and Fort Ethan Allen.

4. Typhoid at the Mary Fletcher Hospital.

5. Influence of out-of-town inmates at the hospital and two children's homes upon the general death-rate and other mortality figures as given in Table No. 1.

In regard to the first point, little can be said from the sanitary aspect beyond what has already been said. We have, so far as I know, no analytical data to prove such an accident. Specimens of water taken over our own intake resemble very closely those taken from our service pipes. On the other hand, it is perfectly evident from the slight analytical difference between water taken in the region of the intake and much nearer shore, as is brought out in Mr. Leighton's paper on the "Pollution of Lake Champlain," that a large admixture of shore water would be possible without any appreciable analytical change to prove its presence. This problem seems to me to be one which must be attacked from an engineering rather than from a sanitary standpoint.

With regard to the second point suggested by Mr. Baker for discussion, *i. e.*, the dangers from the sewage of Burlington as compared with that of Winooski and Fort Ethan Allen, I must take some exception. Mr. Baker passes over the Winooski River as of little importance in the Burlington water problem, while we are convinced that it is a factor of real importance, and perhaps the most dangerous source of infection to our water supply. Our grounds for this opinion are based upon the following propositions which we think are capable of proof:

1. That Winooski and Fort Ethan Allen pour into the river the raw sewage of a population of approximately 5 500.

2. That the topography of the region is such as to render it possible, and even probable, that some portion of this sewage may reach this intake.

3. That we have optical evidence that our water is affected by the river at times of flood.

4. That there is an increase of diarrheal diseases following high water in the Winooski River.

The population of Winooski has increased very materially since the new intake was put in operation in 1894, and Fort Ethan Allen, with its population of 1 500, has been established since that date. This post was first occupied in 1894, when three troops of cavalry arrived there. Since that time it has gradually increased in size, until now it is the second largest military post in the United States, having a continuous population of about 1 500 men. The Winooski River receives the sewage from this post a short distance above Winooski. That the water is highly polluted when it reaches Winooski is amply proven by a large amount of analytical data, some of which is published in Mr. Leighton's paper and some of which appears in the various reports of the Vermont State Board of Health. A striking evidence of the danger of this pollution was brought out by a recent experience in the village. One year ago this winter the Winooski water supply proved insufficient and arrangements were made to use the Burlington water. There was some delay in making the connections and the authorities were forced to allow the untreated river water to flow through the pipes for about twenty-four hours; although people were warned against drinking it, some twelve or fifteen cases of typhoid occurred within the next two weeks.

Float work which has been done by Professor Votey, although not yet completed, shows that the time required for water to pass from Fort Ethan Allen to the mouth of the river is in the vicinity of seventeen hours. The distance from the village of Winooski to the mouth of the river is not over two miles, but on account of its tortuous course, the river flows nearly ten miles in making that distance. In spite of this, the water at the mouth of the river is badly polluted, as has been proven by analytical data taken at various seasons of the year through the ice and in the summer months. This pollution can be traced analytically for a considerable distance from the mouth of the river. The current of the river at its mouth is south. The shore currents of the lake inside the promontories, as proven by Mr. Leighton, are southern.

From the mouth of the river to the intake the distance is about three miles. For $2\frac{3}{4}$ miles of this distance the water is nowhere over ten feet in depth, and for the last quarter of a mile not over twenty-five feet. Now at times of low water it is probably very true, as suggested by Mr. Baker, that the sewage from Fort Ethan Allen and Winooski is largely taken care of by sedimentation and other natural causes, but in times of high water these causes are not in operation, and the highly polluted waters rush over the sand flats at the mouth of the river, strike the southern lake currents, and are carried directly over the region of our intake. That this is true is plainly demonstrable after such a period of high water. At such a time the line of muddy water can be noted passing almost as far south as Juniper Island and circling around Apple Tree Point over the intake. A photograph which I enclose * shows this rather poorly. At such times drift wood coming from above Fort Ethan Allen as far up as Essex Junction is found, from twelve to twenty-four hours after, strewn along the shores of Sunset Bay, having passed the entire distance down the river and over the intake in this time. After such a period of high water, the water coming into our reservoir and passing through our service pipes shows a decided increase in turbidity for several days. That this muddy water carries with it sewage organisms is plainly evident from the fact that we are always able to detect the colon bacillus from our service pipes at such a time, and that such high water is invariably followed by an unusual number of cases of typhoid and diarrhea. Such an occurrence happened this winter following one of our rapid thaws. The water was so muddy that a very perceptible sediment would collect in the bottom of a glass. In the next two weeks there were eight or ten cases of typhoid, and diarrhea was almost universal. At times of high water, of course, the dilution of sewage is great; but sedimentation does not take place, and the rapidity of the flow is so much greater that the reduction by dilution is more than compensated. Furthermore, in such a time of thaw, much filth which has accumulated on the frozen ground is washed into the river. Although the fact of this great dilution will probably prevent any considerable epidemic of typhoid at such times, we believe that in its present position

* Not reproduced. — Ed.

our intake is more in danger by this source of pollution than by Burlington sewage. It is rather a strange coincidence that Fort Ethan Allen was established on the Winooski River, increasing this so materially as a source of contamination, in the same year that our intake was removed so much nearer to the mouth of this river.

Burlington sewage, barring the effect of the winds, is influenced by the general southern shore currents of the lake which sweep it south into and by Shelburne Bay, where it circles north again between Burlington and Juniper Island, when it is separated from the intake by two miles of deep and comparatively still water. Sedimentation is much more operative here than in the moving waters of the river. In the specimens taken by Mr. Leighton and examined in this laboratory, some specimens taken in the deep water on the line between the mouth of Shelburne Harbor and the intake showed no colon bacilli, and showed a water quite nearly like the normal water of the broad lake.

I am enclosing the typhoid and diarrhea statistics from the hospital at Fort Ethan Allen. (Table No. 8.) I was unable to procure satisfactory statistics from Winooski. I am also enclosing a table which shows the number of cases from Burlington which have been examined for typhoid by the Widal reaction at this laboratory. (Table No 9.) I have given figures for the positive and negative cases, as those which failed to give the reaction would naturally come under the diarrheal diseases. It will be noted that the number of positive cases in every instance is larger than the number reported to the health officer. This indicates in my mind that a good many cases of genuine typhoid are probably not reported.

I am inclined to think that the out-of-town typhoid cases which are treated at the hospitals and the two homes are of very little importance, as all of these institutions avoid taking these cases, and when so taken they appear on the reports.

TABLE No. 8. — Statistics of Typhoid Fever and Diarrhea at Fort Ethan Allen.

Year.	1906	1905	1904	1903	1902	1901	1900	1899	1898*	1897	1896	1895	1894
Typhoid	—	3	1	1	—	1	—	1	6	—	1	1	4
Dysentery	—	1	—	4	3	5		1	6	—	1	—	—
Diarrhea	7	23	11	21	40	31	—	21	17	17	15	6	5

* In the fall months of this year (1898) the First Vermont Volunteers were stationed here, coming from Camp Thomas. During the time of their stay there were fifty-five (55) cases of typhoid treated at the Post Hospital. These cases do not appear in the above table.

The case of dysentery noted (1905) was acquired in Philippine Islands.

This excerpt from Post Hospital records dates from October 1, 1894, to present month of March.

All records for the volunteer forces stationed here at any time have been sent to surgeon-general's office, Washington, D. C.

C. R. Robbins,
Captain and Assistant Surgeon, U. S. A.

TABLE No. 9. — Burlington Fever Cases which have been Subjected to the Widal Test at the Laboratory of Hygiene, Burlington, Vt.

Year.	Positive.	Negative.	Year.	Positive.	Negative.
1898	41	31	1902	20	24
1899	43	22	1903	29	68
1900	52	31	1904	56	32
1901	37	54	1905	77	113

Mr. C. P. Moat.* Since any statement of my opinion on the question of the influence of the Winooski River on the intake of the Burlington water works would be simply a repetition of Dr. Stone's remarks, as our ideas on this question have always been in full accord, I will simply submit some additional data on the quality of the water of the Winooski River. In addition, I send as much information on the number of cases of typhoid fever in the village of Winooski as is at present available (Table No. 10).

* Chemist, Vermont State Board of Health, Burlington, Vt.

These data are taken from the number of specimens sent to the Laboratory of Hygiene for the Widal test and are probably more accurate than the number of cases reported to the health officer, which is not available at this time.

In the table of water analyses (Table No. 11), the samples were taken from the Winooski River in the following places:

I. Several hundred feet above the outlet of the sewer of Fort Ethan Allen.

II. Below the outlet of the sewer of the fort (sample was taken near shore and current of river was towards that shore).

III. Above the upper dam at the village of Winooski.

IV. Below the village of Winooski. (Sample was discolored and contained very high chlorine, probably caused in part by mill waste, but as yet we have had no opportunity for further study of this problem. We hope to do more along this line this spring.)

V. Sample taken at the temporary intake of the Winooski Aqueduct Company at the American Woolen Company's mill at village of Winooski. This sample was taken at the time mentioned by Dr. Stone, when the river water was allowed in the mains of the Winooski Aqueduct Company for twenty-four hours, causing much typhoid, as shown in year 1903-4 of Winooski typhoid table.

VI. Sample taken at railroad bridge near the mouth of Winooski River.

Besides these analyses, further data may be found in the Water Supply Paper, United States Geological Survey No. 121, Tables xxii and xxiii and Fig. 7.

TABLE No. 10.—SPECIMENS EXAMINED AT LABORATORY OF HYGIENE FOR TYPHOID FROM WINOOSKI.

Year.	Results.		
	Positive.	Negative.	Total.
Nov. 1, 1898 – Dec. 1, 1900.	5	11	16
1900–1901	6	16	22
1901–1902	2	7	9
1902–1903	4	9	13
1903–1904	18	38	56*
1904–1905	7	18	25

* Year in which river water was used for twenty-four hours.

TABLE No. 11.—ANALYSES OF WATER FROM WINOOSKI RIVER. (PARTS IN 1 000 000.)

	Date of Collection.	Appearance.			Odor.		Residue on Evaporation.			Ammonia.		Chlorine.	Nitrogen as		Oxygen Consumed.	Hardness.	Bact. per 1cc	B. Coli.
		Turbidity.	Sediment.	Color.	Cold.	Hot.	Total.	Loss on Ignition.	Fixed	Free.	Albuminoid. Total.		Nitrates.	Nitrites.				
I	Nov., 1905	sl.	sl.	14	1e.	—	71.	20.	—	.008	.106	.7	.230	.000	—	41.6	300	present
II	Dec., 1905	dec.	,,	12	5d.	—	60.	10.	—	.150	.250	1.4	.250	.000	—	——	420	,,
III	Nov., 1905	sl.	,,	24	2e.	—	70.	10.	—	.010	.098	1.1	.200	.000	—	41.6	500	,,
IV	,, ,,	,,	,,	30*	,,	—	82.	22.	—	.014	.116	3.5	.140	.000	—	48.6	400	,,
V	Jan., 1904	dist.	,,	30	3c.	—	87.5	11.5	—	.076	.100	1.6	.600	.003	—	62.9	1 000	,,
VI	Mar., 1904	dec.	cons.	30	2v.	—	51.8	14.	—	.068	.194	1.6	.340	.001	—	36.	many	,,

* Discolored.

MR. M. O. LEIGHTON.* The subject of this paper is of great interest to the writer. During the summer of 1904 he had occasion to look into it to some extent in connection with an investigation maintained by the United States Geological Survey upon the pollution of Lake Champlain. Among the results of that investigation was a demonstration of the fact that, although the water in the broad lake did not contain bacillus coli communis, the entire area in front of the city of Burlington, and from thence northward to and beyond Apple Tree Reef, the point of the present intake, was infected by Burlington sewage. This was shown by the almost constant appearance of coli in the samples collected.

Mr. Baker's first table shows that, although no relation is apparent between the total deaths and the number of deaths from typhoid, the number due to diarrheal diseases appears to fluctuate with the total in an extremely interesting manner. The large number of fatalities from diarrheal diseases is a distinct factor in increasing the general death-rate at Burlington.

Another interesting fact shown by Table No. 1 is the apparent faithfulness with which the cases of typhoid fever have been reported in Burlington since 1898. The writer is now referring to those cases which are well marked and easily diagnosed and recognized by the practitioner. It appears from a review of the report of the Medical Commission appointed to investigate the origin and spread of typhoid fever in the United States military camps during the Spanish War, that 7.61 per cent. of the typhoid cases were fatal, while American hospital experience in general seems to show that about 9.25 per cent. are fatal. Assuming that 8 per cent. is a conservative figure, it will be seen that there is an unusual faithfulness on the part of the physicians in reporting typhoid cases, the reports in some years being equal to the probable actual cases as comported upon this basis.

Of course we know that a great many of the deaths reported as being due to diarrheal diseases were actually the result of typhoid, and if the numbers were known, they would probably constitute a surprising proportion of the whole. It will be remem-

* Chief of Division of Hydro-Economics, United States Geological Survey, Washington, D. C.

bered that the investigation of the Medical Commission above referred to showed that the army surgeons diagnosed about one half the cases of typhoid fever in military hospitals during the Spanish War, and it has not been shown that physicians in civil life betray a much greater degree of success in general diagnostic ability than those in the army.

Another interesting point emphasized by Table No. 1 is that every important change that has been made in the sewerage and water-supply systems of Burlington has been followed by a marked reduction in either the number of deaths from typhoid or from diarrheal diseases, and it illustrates how misleading may be the statistics of a single year or of a short period. It will be noted in Table No. 1 that there were 79 deaths per 100 000 from typhoid in 1884, but in 1885, the date when the main outlet sewer was moved one-half mile farther away from the water intake, there were only 8 deaths per 100 000. Similarly, in 1894, the year after the removal of the water intake from the northern dock limit in the city out to Apple Tree Reef, there was a reduction in the number of typhoid deaths of from 63 to 12 per 100 000, and this reduction, by the way, persisted for several years. It is further particularly interesting to note that in 1898, the date of the placing in commission of the new storage reservoir, there followed an enormous reduction in the deaths from diarrheal diseases. It appears that none of these changes have effected a permanent benefit in Burlington, and yet, if the statistics immediately following the dates of those changes be taken alone, wondrously deceptive statements may be made.

Mr. Baker's Table No. 2 shows that among the fatal diarrheal diseases, cholera infantum comprises a very large proportion. Presumably, this infantile trouble is due in only a minute degree to the public water supply, and the deaths probably all occurred during the hot months. It would be interesting to have a statement of the seasonal distribution of the deaths from these diseases, because it is especially important to know whether the greater proportion of them, other than cholera infantum, occurred during the winter months, when the lake is coated with ice. If such is the case, the evidence against the water supply would be even more conclusive than it appears from the results presented. It would

be interesting, too, to compare the diarrheal morbidity in Burlington during the winter season with that in Michigan City, Ind., where each winter, up to the time that the Chicago sewage was diverted from Lake Michigan, they had an epidemic of what was locally known as "winter cholera," due undoubtedly to the infection of the lake supply by Chicago sewage. The infection was rapidly transmitted along the south shore of the lake by prevailing northerly winds and confined and concentrated under the ice sheet which usually forms there.

In connection with Table No. 2-A, which shows that during about one third of the time since the year 1880 Burlington has had an abnormal typhoid rate, it is interesting to notice that all the abnormal years, except two, occur previous to the extension of the water intake to Apple Tree Reef. From 1880 to 1894, abnormal typhoid rates appear about every second or third year, but during the eleven years subsequent to this extension, the rate has been abnormal during two years only. The same condition is exemplified in the deaths from diarrheal diseases. Accepting the rate of 20 per 100 000 as an arbitrary division between normal and abnormal diarrheal disease death-rates, it will be seen from an examination of Table No. 1 that during the years up to 1894, the abnormal death-rate largely predominated, while since that time the abnormal rate has appeared only on three occasions.

Table No. 3 emphasizes the improvement brought about by the extension of the conduit in the year 1894, and shows clearly the gradual return to the old conditions during more recent years. Why, in the lapse of years since the extension of the intake, there should have been a gradual return to former conditions, is a question which can hardly be answered with the present information. There are some reasons for believing that the continued discharge of Burlington sewage into the lake has increased the infected area until it now reaches to the intake at Apple Tree Reef. The series of samples taken in front of Burlington in September, 1904, along the line shown in Fig. 7, page 87, of Water Supply and Irrigation Paper No. 121, United States Geological Survey, would seem to indicate a very general extension of the infected area, coli communis being present in nearly all samples. That this is not a natural condition is shown, as stated at the beginning of this dis-

cussion, by the fact that in the broad lake, coli communis does not appear to be present.

There is also some reason for believing that the conduit extending from the pumping station to Apple Tree Reef may have developed leaks, which are responsible for a return of the old conditions of typhoid and diarrheal morbidity. This matter could and should be thoroughly investigated. The conditions of the investigation are such that the work would have to be directed along bacteriological lines and, in fact, just here is presented one of the unmistakable cases in which the value of bacteriology in connection with water investigation is shown. In order that the work may be of value and the results be made dependable, special preparations should be made, and a competent man should give his entire attention to every detail of the investigation.

Daily and, if possible, semi-daily samples should be taken from the mouth of the intake at Apple Tree Reef and from some point along the conduit after it emerges from the lake, possibly at the pumping station. These samples should be taken in series. Bacterial counts and tests for coli communis should be made, and a comparison of the two series should show conclusively whether or not the conduit admits infected water through leaks developed since the laying thereof. Besides being of immense local value, such an investigation would be of interest from a general scientific standpoint and would be useful reference for all future water investigations of a like character.

One of the most important evidences concerning the culpability of the water with reference to the production of typhoid in Burlington is contained in Table No. 6. It is especially significant that the highest typhoid rates occur during the season when the lake is covered with ice, when there is, one might say, a short circuit between the sewer outlet and the water intake. If we examine the seasonal distribution of urban typhoid throughout the United States, it will be found that quarterly periods from highest to lowest are (1) September to November; (2) December to February; (3) June to August; and (4) March to May; while, according to Mr. Baker's groupings, the highest quarterly period at Burlington is January to March, during which season Lake Champlain is generally coated with ice.

Mr. Baker's Table No. 5 affords a concrete illustration of the value of coli tests in revealing dangerous pollution in a water, while, on the other hand, the general futility of the nitrogen determinations for such purposes is amply demonstrated. In fact, throughout all the Burlington investigations, the nitrogen determinations have been of no aid in tracing the cause of disease and, as a whole, the case forms one of the best of a great many which demonstrate the general uselessness of the time-honored determinations of free and albuminoid ammonia, nitrites and nitrates, in surface water investigations.

Mr. Baker's observation that the pollution of Winooski River has probably very little to do with the infection of the water supply is supported to a large extent by observations of the writer. There are times, however, during seasons of prevailing northerly winds and of floods in the Winooski, when the path of the stream may be clearly marked along a course extending well to the south and not far from the present water intake. The general trend of the current, however, is northward from Winooski River, and it is therefore probable that such infection does not, in the majority of cases, extend as far south as Apple Tree Reef.

Mr. Allen Hazen.* Mr. Baker's paper is an extremely interesting contribution to our knowledge of the relations between water supply and public health. The most unfortunate feature connected with the case is the uncertainty as to whether the intake is tight, and whether all the water comes from the intended place, or whether there are leaks in the pipe line which admit more highly polluted water from the bay; and it seems particularly unfortunate that this matter was not settled beyond question before Mr. Baker completed his studies and made his report.

Mr. Baker has referred to the investigations of the use of polluted water by cities, made twelve or fifteen years ago, in making which I had the privilege of being associated with our honored President, Professor Sedgwick. The change that has taken place since that time in the aspects of this question is a most significant commentary on the development in the interval; and I wish to make a few comparisons which may help us to realize the extent of the progress which has been made.

* Civil Engineer, New York, N. Y.

At the time mentioned, the relations between public water supply and disease were by no means generally recognized. And this is the more surprising, as many of the larger American cities were using grossly polluted waters, and as a result suffered from death-rates greatly in excess of what they would otherwise have had.

The question as to the accuracy of the vital statistics at our disposal then was far greater than it is now, but the effect of the polluted waters upon the health of the communities using them was so great that no refinements were necessary to bring out the general relations which existed. The contrasts between the large cities using different kinds of water were so great that it was hardly conceivable that errors in classification or in failures to report deaths, however flagrant they might have been, would have sufficed to modify the conclusion that the enormous excess of sickness and death in some American cities was directly due to the use of grossly polluted water supplies.

These conclusions, nevertheless, were at first bitterly contested in many quarters; but as they were studied further the logic of the situation became apparent, and they came to be generally accepted. Since then affairs have changed; and while there are still some black sheep in the fold, on the whole there has been a great improvement in the average quality of the public water supplies of the country, and the recognition of the relation between the character of the water supply and the health of the community has been a tremendously important element in bringing about this improvement.

At that time such an investigation and analysis as Mr. Baker has now made of the pollution of the Burlington water supply would have been out of place. Then it would have been difficult, perhaps impossible, to have established the relations between the moderate pollution of the water and the moderate increase in the death-rate from certain causes resulting from it, which Mr. Baker has found to exist in Burlington. Now it is possible. It is possible because, in the first place, the proposition that such a relation does exist is a corollary of the main proposition that highly polluted waters do produce excessive death-rates; and it is further possible because, in spite of existing defects, the information available to aid in the study of such a problem to-day is

vastly better than could have been obtained a dozen years ago. The vital statistics are better, and the laboratory examinations of the water are vastly better than could possibly have been obtained at that time.

This investigation of Mr. Baker's, I think, is but a typical case of many such investigations that are going to be made to determine the effect of less grossly polluted waters upon the public health. The methods of investigation are improving as time goes on, and by proper use of them it is possible to follow the relation between water supply and disease further down the line and carry it to degrees of pollution the effects of which were at first too small to be observed or studied; and such investigations will extend our knowledge of the subject and will allow better and more reasonable discussions of the pollutions of water supplies, and the reasonable standards to be maintained in protecting waters from such pollutions, and in applying corrective measures where the pollutions themselves cannot be suppressed.

In discussing Mr. Crandall's paper, presented to this association in September, 1895, I ventured the statement that ten million dollars was not an overestimate of the loss in Chicago in one year, due to the polluted condition of the public water supply. This was based on typhoid statistics alone. Since that time I have become convinced that typhoid fever, as Professor Sedgwick suggested at the time, and as Mr. Baker now confirms, is wholly inadequate to measure the extent of damage caused by a polluted water supply, and the figure then given for Chicago was probably far below the real damage which resulted to the citizens of that city from the condition of the public water supply; and the loss was so great that it would amply justify almost any measures which might be necessary for the correction of the difficulty.

In the case of Burlington the amount of sickness and death which can be attributed to the water supply is small in proportion, but still, when carefully followed out and estimated, and reduced as well as it can be to a financial basis, it may be, and very likely is, far more than enough to justify whatever expense may be necessary in changing or improving the supply, as for instance, by filtration, as Mr. Baker recommends.

The day is rapidly passing when cities can continue to exist and

prosper while killing their citizens by impure water. Already it makes a great difference with the prosperity of a city whether its water supply is healthful or not. It will not be many years before intelligent people will refuse to live in a city where they are subject to such dangers. The question is no longer whether or not it is worth while to furnish good water. It is getting to be whether a city shall continue to exist; for I believe the day is at hand when a city cannot exist in any adequate and satisfactory sense without a reasonably pure and wholesome public water supply.

MR. G. W. FULLER.* Mr. Baker's paper is an excellent one, suggesting broader and more reliable lines for water-works people to consider in dealing with the quality of public water supplies. The writer is heartily in sympathy with the studying of diarrheal diseases and their relation to drinking water. There is no doubt about polluted waters materially affecting general death-rates in this manner. Changes from polluted to relatively pure waters cause a marked reduction, not only in typhoid fever, but also in the general death-rate, principally through the influence upon the latter of deaths from diarrheal diseases. For some time there has been a growing feeling among sanitarians that this subject should receive more attention, and Mr. Baker is to be congratulated on his careful, painstaking data regarding the Burlington evidence.

The compilation of such statistics to show their influence upon the quality of public water supplies is not entirely new. In fact, it is understood that quite similar statistics were prepared under the direction of Mr. Rudolph Hering relative to the public water supply of Louisville, Ky., in 1892. Mr. Baker's paper shows, of course, in a striking manner the importance of having death certificates properly prepared, both as regards the diagnosis of the diseases producing death and their classification for accurate and ready reference in municipal records. In some ways the Burlington situation as to vital statistics is unusually free from complications as to other drinking waters than the public supply, although it is not free from questions of other general sources of infection, as mentioned by Mr. Baker in his paper.

Experiences of communities in discharging sewage into, and taking their water supply from, the same body of water are always

* Civil Engineer, New York, N. Y.

interesting. Seldom has this proposition been faced with satisfactory results, although there are some instances where, under special conditions, this seems to have been true. The general question of the pollution of large bodies of water by sewage at points some distance removed from the point of sewage discharge is, of course, of growing importance to the sanitarians. To the writer it is particularly so as it bears indirectly upon the questions of foreshore pollution and the effect of sewage upon the shellfish industry. Views upon these matters are not so definite as they should be, and all carefully compiled data bearing upon the subject are of importance in getting views crystallized upon reliable and definite lines.

By those who have had to do with water supply matters for cities on the great lakes it will be noted at once that the Burlington intake, although three miles removed from the principal outfall sewer, is in water of a depth of only 30 feet, and that the intake is turned upward until it reaches within 14 feet of ordinary low water. In this respect the Burlington supply differs materially from those of a number of cities having relatively good water from the great lakes. Reference is made to the fact that the lake water near the Burlington intake is so shallow that sediment, some of it presumably of sewage origin, is stirred up during heavy winds, and further that the supply is not protected by stratification from pollution by intermingling with the upper water. As to the effect of wind disturbances, it may be said that experience shows that severe storms may disturb large bodies of water to a depth of some 35 feet below the mean level. Stratification is of great importance, for instance at Milwaukee, where the water is drawn from Lake Michigan at a depth of some 80 or 90 feet, from a point where the bottom water remains at about maximum density very near all the time. In this way, although sewage may, perhaps, at times be driven by currents to the vicinity of the intake, the upper water, of lighter specific gravity and, perhaps, of doubtful quality, does not reach the intake. The latter is polluted, if at all, only by those bacteria which by chance settle from the upper water to the intake. The influence of this is presumably no greater than that of the residual bacteria in the effluent of a well-managed filter plant.

Several years ago the writer had occasion to investigate this matter at places both on Lake Erie and Lake Ontario. In the former lake it is probable that stratification hardly takes place to a degree to give much assistance in securing a good source of water supply. But in Lake Ontario, in the vicinity of Oswego, it was found that at a depth of 80 feet the water remains stratified with the exception of short intervals in the spring and fall, when there was an overturning from top to bottom. While stratification existed, the water at the bottom, with a lower temperature and higher density, showed no measurable effect of pollution even when winds and currents drove some of the harbor water along the surface to the vicinity of the proposed intake. Should such wind and current conditions prevail during the comparatively short period of overturning in the spring and fall, when stratification is absent, such protection could not be counted upon. With water from such a source supplied without filtration, it becomes desirable, and in some cases necessary, to be prepared to draw water from storage during conditions favoring the passage of polluted water to the vicinity of the intake.

Another point of some interest in this connection was encountered in a study of the water supply of Buffalo and suburbs, viz.: That winds generally produce an undercurrent moving in the opposite direction to that from which the wind blows. In this way, pollution, either through surface or undercurrents, may be carried probably to a greater distance than is generally appreciated.

Pollution of water supplies does not have to occur every day in the year in order to produce serious trouble. While it is important to settle the question, as Mr. Baker suggests, of whether there is a leak in the intake of the Burlington supply in order to show the effect of an unfiltered water supply from the present intake upon the consumers, it is not unlikely that during a few days in the year the water from the intake itself, due to conditions of wind and weather, is much below normal quality.

In the opinion of the writer the tests by so-called presumption methods for the presence of fecal bacteria in water require great caution in interpreting results.

Dr. George A. Soper.* It is unusual to find a paper upon the

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* Consulting Sanitary Engineer, New York City.

effects of impure water which has been so carefully prepared as the one under discussion. It is one of the most thorough and painstaking studies which have appeared, and the city of Burlington, no less than the members of this association, should feel indebted to Mr. Baker and those whose labors have contributed to this work.

The single point which I desire to refer to in discussing the paper has to do with the amount of sickness which can fairly be attributed to the water. Should we go beyond the statistics of typhoid fever in estimating the extent of the connection between a water supply and disease? and if so, how far? In other words, what forms of illness may be communicated by such a water supply as that of Burlington, and how can the fact of the connection of these diseases with the water supply be established?

In the present state of our knowledge, it seems desirable to restrict our view of the possible consequences of drinking sewage-polluted water to diseases of the bowels; not that the impurities in such water may not, in some cases, cause other disorders, but because the chances of their doing so are too remote for practical consideration.

Probably the most important and difficult disease to investigate in connection with a water supply is typhoid fever. Because of the many forms which typhoid may take and the existence of popular delusions concerning it, it is doubtful if the extent of this disease is ever known with accuracy.

In investigating the cause and extent of existing outbreaks of typhoid fever, it has been my custom for years to study not only the cases of sickness which were readily recognized to be typhoid, but also those forms of illness which, by any chance, might be typhoidal in nature. I have generally included in this list cases reported as paratyphoid, paracolon, enteric fever, fall fever, dysentery, enteritis, diarrhea, and malaria. Recently I have added pneumonia, bronchitis, and tuberculosis, for I have not infrequently found genuine typhoid treated by physicians as these diseases. All such cases have been regarded in my investigations as of a doubtful or unsettled character until a special study of them could be made to ascertain with positiveness their real nature. Even with these precautions, it has been impossible to

detect every case of typhoid. Exceedingly mild cases are often not reported by physicians at all. Sometimes erroneous or fanciful names are deliberately given to typhoid with the object of hiding the nature of the disease.

The kind of study made necessary by such an investigation requires the services of a number of trained assistants and the use of a laboratory for examining blood and other pathological and sanitary work. But these adjuncts are what should be available in investigations of epidemic diseases wherever an attempt is made to carry them on thoroughly, and I have generally found it practical to obtain all the facilities needed. This was so at Ithaca, N. Y.; Watertown, N. Y.; Williamstown, Mass.; Lawrence, N. Y.; and elsewhere. My chief difficulty has been in obtaining competent assistants.

In inquiring into the past records of disease no such satisfactory measures can be used to determine the exact number of typhoid cases. It may always be assumed that the number has been larger than that reported, but the ratio between the real number and the number indicated in the health records is never ascertainable. Cities which have the most typhoid are apt to be the most indifferent to it; their records, also, are likely to be the most inaccurate.

Mr. Baker has presented in his paper records of diarrheal diseases beside typhoid; not, apparently, with the idea that many of these cases were perhaps genuine typhoid, but because it seemed fair to suppose that many of them had been produced by the water supply. This appears to me to be a natural conclusion. Conditions which result in the contamination of a water supply with the germs of typhoid are also likely to lead to its pollution with the germs of other diseases. It is probable that a water supply is sometimes infested with the germs of several intestinal diseases at the same time. This is, I think, sufficiently indicated by the fact that in any large typhoid epidemic, various other diarrheal diseases, which are not typhoid, are apt to be met with. The diseases produced depend upon the nature of the microorganisms contained in the filth which defiles the water. At Ithaca there were several annual visitations of diarrheal diseases before the extensive epidemic of 1903; during the progress of that

epidemic several diarrheal diseases other than typhoid occurred and were believed to have been caused by the water. The typhoid epidemic at Watertown, N. Y., in 1904, was preceded by an epidemic wave of diarrhea.

Yet I am inclined to believe that records of other diarrheal diseases beside typhoid should be used with caution. So many other conditions may account for these disorders that it seems unsafe to ascribe an undue excess of them to water unless the other factors which enter into their etiology have been eliminated after careful study. The industrial conditions which prevail in a city may have a marked effect upon the infant mortality, and infant mortality usually represents the major part of diarrheal diseases not typhoid. The nationality of the population and their degree of intelligence and education are important factors in the matter. Above all, the condition of the milk supplies, the spring water supplies, the severity of the weather, the clean or dirty condition of the city and the housing of the laboring classes are conditions which should be taken very carefully into account before drawing any conclusions as to the cause of an undue prevalence of diarrheal diseases. In investigating these questions, whether they relate to present or past conditions, the coöperation and assistance of local physicians can sometimes be used to advantage, for although they are often poorly informed in matters of hygiene and the more scientific aspects of the causes of disease, their opportunities for observation are unrivaled and they are sometimes well informed.

Among the manifest difficulties to be met with in investigating the past records of diarrheal diseases in a city are those which rise from the fact that the conditions which should be studied in order to properly interpret the statistics are matters of history, often imperfectly recorded, and no longer subject to minute investigation. The making and interpretation of vital statistics is subject to more error than almost any other form of statistical work.

It is well known to the members of this association that what appears to be one of the most remarkable results of introducing a supply of pure water into a city whose water supply has previously been impure is a seeming reduction in the occurrence of

diseases whose causes have no conceivable connection with drinking water. The statistics sometimes make it appear that the number of cases of practically all forms of disease has been reduced. If we were to credit the records and believe this theory, it would be necessary also to believe that its converse was true,—that the amount of sickness and death from all forms of disease was increased by impure water. If this opinion was held, it would be necessary in such a study as this one of Mr. Baker's to take account of every case and death known to the health authorities. I am far from saying that this would be an undesirable proceeding, but I do not think it would be warranted on the ground that the theory just alluded to was correct.

In fact I doubt whether it is true that the introduction of a pure water supply reduces the general death-rate as much as appears. It seems possible that often as much of a change takes place in the methods of keeping the records and interpreting them as in the health of the people, excepting so far as enteric diseases are concerned, and even here the beneficial results may be unintentionally exaggerated. In the sanitary awakening which a city experiences when a pure water supply is introduced, the condition of the public health and the work of the health office assume an importance and receive an amount of attention which they have never before known. From a position of comparative obscurity and neglect, the business of the board of health emerges into one of great prominence and responsibility. Everybody looks to the board to mark with official precision the extent of the improvement. Those persons who have to do with the records naturally share in this interest and desire that the city shall have as clean a bill of health as practicable. The report of each case of sickness and death is scrutinized with extreme care. Physicians are on their mettle. As few cases and as few deaths are charged against the city as is legally possible. Not seldom the sickness and death of persons from outside of the city who are taken ill within the limits, or are brought there for treatment, are recorded, after the installation of the new water supply, as having occurred in the places where the deceased claimed residence. In these ways the vital statistics are sometimes influenced without any intention on the part of any one to deceive.

When it is appreciated that cases of the commonest diseases due to impure water supplies often differ so markedly in appearance that physicians make mistakes in diagnosing them, that boards of health are often lax in keeping the records, that many other factors than the water supply contribute to the spread of what are known as water-borne diseases, and that the time and skill necessary to investigate the facts are seldom available, the value of such a long and careful study as Mr. Baker has made becomes evident.

Condensing my views on the subject to a simple and brief form, I should say that in studying the possible relation between a water supply and the health of a city, it is desirable to take account not only of the occurrence of typhoid, but of practically every other form of disease which occurs in the vicinity. The official records should be used more as clews to the truth than as evidence which needs no verification. Wherever possible, the investigation should call to its aid modern methods of pathological study. The value of the investigation will usually depend not only upon the official records or other information which may have been already collected, but also upon the skill and thoroughness with which the information thus offered is studied, checked, amplified, and interpreted.

The investigation of the Burlington situation has been fortunate in some respects. The statistical records seem to have been remarkably full and reliable, and the situation has been studied with a degree of thoroughness, competency and impartiality which, up to this time, has been very unusual. In the future, sanitary investigations of a far more exacting character than we have been accustomed to will have to be made. It is a vast mistake to suppose that only those sanitary matters need investigation and correction which are conspicuously dangerous. The investigation and correction of the more subtle and obscure causes of disease are at least of equal importance.

Dr. John S. Fulton.* The statistical exhibit which Mr. Baker has made of certain causes of death in Burlington between 1879 and 1905, and the arguments which he makes for a more liberal use of mortality data in determining the sanitary quality

* Secretary, State Board of Health, Baltimore, Md.

of the public water supply, seem to me most interesting. It is not surprising that Mr. Baker should have overlooked an important source of fallacy which affects all vital statistics, since the source to which I refer lies wholly in the domain of medicine, and is but little known outside the medical profession. It is difficult to bring medical men to realize the unreliability of the data which they themselves supply. All mortality statistics are based on the death certificate, and non-medical statisticians generally regard the death certificate as of fixed interpretation. As a matter of fact, however, medical men seldom write a death certificate with any appreciation of its utility as a contribution to vital statistics.

Its use as a basis for a burial permit is the only significance of a death certificate to a physician who is writing such a certificate. When these small documents in large numbers come up for statistical treatment their proper statistical reference is sometimes very difficult to determine. Not one physician in a thousand knows or cares anything about the nomenclature employed for statistical purposes. These nomenclatures themselves have their faults, and the very best that medical statisticians can do in these days is to move toward some sort of uniformity.

Too often the mortality data of American cities are made over into statistical tables by inexpert persons who are quite incompetent to translate the phraseology of a certifying physician into the rigid nomenclature of a statistical classification. In some items the terms of the classifications are vague, and very often the phraseology of a physician is vague. There is hardly any class of causes of death which admit so great a variety of vague terms as those diseases which are known as diarrheal diseases.

I suppose the term *typhoid fever* represents to the average layman a very definite cause of death. This term in pathology assuredly has a definite significance, but in clinical medicine the term "typhoid fever" in American practice does not occur in more than 60 per cent. of the certificates recording deaths which are really due to typhoid fever. At the present moment 40 per cent. of the cases of typhoid fever either wholly escape the diagnosis of attending physicians, or else, when death occurs, are recorded under some more or less vague name. If we trace typhoid fever back in the statistics we will find that the percentage

of error increases the farther back we go, and for twenty-five years backward we find some twenty-five or thirty more or less confusing phrases employed by physicians to indicate deaths which, in all probability, were due to typhoid fever. Medical statisticians have but gradually come to understand this. A note in the first of Mr. Baker's tables says that the Burlington statistician has wisely added to the typhoid deaths the deaths reported as "bilious," "continued," "enteric," "slow," "typho-malarial" fevers. A similar note under Table No. 4 makes a similar exhibit and shows besides that the use of these unmeaning terms was far more prevalent formerly than now, although the absurd term "bilious fever" appears in Burlington's statistics as late as 1901. The terms *enteritis* and *gastro-enteritis* signify, for the most part, the medical man's confusion in the matter of diagnosis, though the statistician may have included in the *enteritis* column a certain number of deaths whose certificates did not bear the word *enteritis*. More than half of the deaths recorded under these two heads ought to be added to the typhoid fever column. If the deaths under five years of age, which have been ascribed to these two causes, could be taken away, 80 per cent. of the remainder could be added to the typhoid fever column without in the least overstating the truth about typhoid fever in Burlington between the years 1879 and 1905. One notes that the enteritis column includes here and there a death from *intestinal colic*. Intestinal colic probably means appendicitis, and the error of diagnosis in appendicitis also increases the further back one goes in the history of mortality. The *colitis* column includes certificates ascribing death to entero-colitis. A majority of these cases (enteritis, gastro-enteritis, entero-colitis, colitis), nearly all of those which were characterized by diarrhea, a duration of two weeks or longer, and ages above five years, should be added to the typhoid fever column. The remainder should be added to the dysentery column, and the small group of cases under the head of ulceration of the bowels should also be added to the dysentery column. The cholera morbus cases, which are few in number, have probably no relation whatever either to typhoid fever or to the water supply. Deaths classified under the heading cholera infantum probably include very few, if any, cases of typhoid fever, and these bear, in all

probability, no considerable relation to the public water supply of Burlington. It will be seen, therefore, that a medical man's views bring him into substantial agreement with Mr. Baker's contention that, besides typhoid fever, several other columns of current mortality ought to be consulted in determining the sanitary quality of a public water supply. It would not be necessary, however, to consult half a dozen different items of mortality, if medical men were firmly convinced of the truth that typhoid fever is the commonest continued fever met with in the United States; for if this knowledge were faithfully reflected in the death certificates, such vague statistical terms as enteritis, gastro-enteritis, enterocolitis, would become emaciated almost to extinction. It will thus be seen that I can agree heartily with the main contention of Mr. Baker's paper and still believe that typhoid fever (frank typhoid fever plus disguised typhoid fever) will still remain the best, and almost sufficient, index of the sanitary quality of a public water supply.

Mr. Baker (*by letter*). I first wish to express my pleasure with the amount and character of the oral and written discussion, and with the fact that the paper has been received and considered as an attempt to present, in a rather tentative manner, some of the broader relations between water supply and disease than can be brought out by typhoid statistics alone. I also wish to say at the outset that some of the vital statistics presented in the paper were included for the purpose of throwing light on the deficiencies in the typhoid statistics rather than because they bear any well-defined relation to the character of the Burlington water supply. In fact, it seems more and more evident to the author that other sanitary conditions at Burlington are in almost as much need of investigation and improvement as is the water supply.

The author is particularly grateful to Messrs. Stone and Moat for their additional data on conditions at Burlington, Winooski, and Fort Ethan Allen. Had these data been in his possession before the paper was written he would have given more weight to the effect on the Burlington water supply of the pollution brought down by the Winooski River. Nevertheless, until further evidence is produced it can hardly be disputed that even

if all pollution were removed from the Winooski River, the Burlington sewer alone would render the water supply so dangerous at times as to make its use without thorough purification unwise. This, it should be said, Messrs. Stone and Moat would doubtless be the first to admit. The author agrees with Dr. Stone that the study of leakage in the water intake is an engineering rather than an analytical problem; or perhaps demands the aid of both methods. Seemingly, it would be a simple matter to test the intake for leakage, and no further time should be lost before doing so. The need of better records of vital statistics at Winooski and more thorough investigations of all reported cases of communicable disease at both Winooski and Burlington is evident. Every reported case of typhoid fever in the two municipalities and at the Fort should be looked into most carefully for the purpose of showing both its origin and its possible or probable effect upon the Burlington water supply. If this were done, and if careful analytical tests of river, lake, and city water were made at frequent intervals, and if at the same time both cases and deaths of diarrheal diseases were systematically studied, much additional light might be thrown on water supply and disease at Burlington and elsewhere. Much of this work properly belongs to the several local authorities, but in carrying it out there might well be coöperation between them and the State Laboratory of Hygiene.

Mr. Leighton is peculiarly qualified to discuss the paper, on account of the studies of the pollution of Lake Champlain already mentioned. His belief that within the past few years typhoid fever has been fully reported at Burlington is in part supported by all the evidence before us, but only in part. That there has been improvement there can be no doubt, but the continued high diarrheal mortality indicates faulty nomenclature, to say the least. This indication is supported by the excess of positive Widal reaction tests, as given by Dr. Stone, over reported typhoid cases, unless the Widal reports include duplicate tests. In 1905, in particular, the positive Widal tests numbered 77, against 32 reported cases of typhoid fever. It is gratifying to note, however, that the Burlington physicians seem to be trying to learn the truth, for in 1905 there were 113 negative as well as 77 positive Widal tests. It may be noted that Mr. Leighton, contrary

TABLE No. 12.—TABLE DESIGNED TO SHOW EFFECT OF ICE OVER LAKE CHAMPLAIN ON TYPHOID MORTALITY AT BURLINGTON, VT.

	Broad Lake. Closed.	Broad Lake. Opened.	Days Closed.	Typhoid Deaths. Jan.-Mar.	Typhoid Deaths. Year.
1890	February 10, 21	February 11, 28	13	2	
	March 7	March 12			4
1891	January 27	January 31	42	3	4
	February 14	February 27			
	March 8	April 2			
1892	February 14	April 3	49	2	7
1893	January 16	April 12	86	7	10
1894	February 6, 12	February 10	35	1	2
		March 15			
1895	February 7	April 19	71	0	1
1896	February 17	April 17	60	1	4
1897	January 31	April 10	69	0	2
1898	January 30	March 16	45	3	5
1899	February 1	April 20	78	1	2
1900	February 28	April 19	50	4	7
1901	February 1	April 11	69	3	5
1902	January 30	March 28	57	0	2
1903	January 24	January 30	27	0	3
	February 19	March 12			
1904	January 19	April 13	85	1	7
1905	January 23	April 13	80	2	3
	Total Deaths	(average closure)	57	30	68

The bay at Burlington and also the Winooski River would be covered with ice when the "broad lake," which is here some ten miles wide, is not frozen from shore to shore. Earlier statements regarding lake closure are not available. The observations given were recorded by Mr. Charles Allen, of Burlington, Vt.

to Dr. Stone, suggests bacterial tests to ascertain the tightness of the intake. Mr. Leighton's remark to the effect that the monthly distribution of typhoid (Table No. 4) shows that the disease is at its worst when the lake is covered with ice (or really in the months when such a covering would be expected) leads me to include a table (Table No. 12) compiled from the city reports of Burlington, showing for the past sixteen years the dates on which the "broad lake" closed and opened opposite Burlington, the days closed each winter and the number of typhoid deaths for the January–March quarters of the corresponding years, and the total numbers of typhoid deaths for the several years.

While the figures in detail do not show as much connection as might be expected between a disproportionate amount of typhoid in the first quarter of the year and a long period of ice closure of the lake, yet it may be noted that, in 1893, the worst typhoid year indicated by the table, 7 of the 10 typhoid deaths occurred

in the first quarter, and in that year the lake closed earlier and remained closed longer than any other year of the sixteen. The following winter was an open one, and in August (1894) the water intake extension was put in use. Only two typhoid deaths were recorded, one of which was in the first quarter. In 1895, the lake was closed seventy-one days, but there was only one typhoid death, and that in the later part of the year. The effect of the new intake was shown in this and a number of subsequent years, but beginning with 1900, typhoid again rose. With the exception of 1900 and 1904, typhoid has been highest when the lake was closed longest, and in three of the six years more than half of the typhoid deaths have been in the first quarter of the year. It should be noted that the bay and river, the region of sewage influence, are closed earlier and longer than the broad lake, and that the table inserted in this discussion shows that for the whole sixteen years 30 of the 68 typhoid deaths recorded were in the first quarter of the year when they would be least expected, pointing undoubtedly to the protective effect of ice covering on the typhoid germs in the lake water. With the recurrence of typhoid from 1900 on, only 10 of the 27 recorded typhoid deaths were in the January-March quarter, indicating that the typhoid infection, from whatever source, is becoming more generally distributed throughout the year.

Mr. Weston suggests that hospitals in general have little effect, that need be considered, on the vital statistics of cities. This may be true for large cities, for, as Mr. Weston says, the out-of-town patents who die in such hospitals may be balanced by the people of those cities who die elsewhere. But in a city like Burlington, with no hospital in near-by places, the out-of-town patients are less likely to be balanced in such a way. Dr. Stone also states as his belief that the hospital at Burlington has little effect on the number of typhoid deaths, since the taking of typhoid cases is avoided there. Probably the Burlington hospital does have but little effect on typhoid in Burlington, but doubtless it accounts in part for the high general mortality in that city. The two childrens' homes, taking children from without the city, add to the under-five population, and therefore contribute to the unduly high infant mortality.

It is to be regretted that the Louisville figures mentioned by Mr. Fuller could not be included in the discussion. The author is informed that Mr. George C. Whipple has also collected some diarrheal statistics in connection with water supply studies at Cleveland, Ohio. Mr. Fuller's remarks on the need of caution in interpreting results obtained with presumptive methods for determining fecal bacteria deserve attention in connection with the large number of colon bacilli reported as found at Burlington.

Dr. Soper's remarks, like those by Mr. Hazen and others, endorse the author's general idea of broadening the scope of the vital statistics commonly used in studying the effects of water supplies on the public health. Dr. Soper would go even further afield, taking in other than diarrheal diseases, not because these are caused by bad water, but because, for one reason or another, they cover up many typhoid cases and deaths. The author agrees with Dr. Soper that the diarrheal statistics should be used with caution and that a variety of other factors than the water supply should be considered in studying diarrheal mortality. It is particularly desirable that this should be done at Burlington, where, as the author pointed out in his report to that city in 1905, the sanitary condition of the milk supply has received very little attention as yet, and where housing conditions and infant feeding, among a considerable part of the population, are probably bad.

The association and the author have reason to be thankful for the discussion contributed by so eminent a vital statistician as Dr. Fulton. It is only fair to the health officials of Burlington for the author to take upon himself the full responsibility, as he thought he made plain in the paper, for searching out in the twenty-six annual reports and grouping together by years and classes all the statistics included in the tables, and for making the reclassifications indicated by footnotes. In no one of the Burlington reports is there a comparative study of any of these mortality figures by years, nor did any of the health officers, so far as the reports show, ever reclassify as typhoid fever a death reported by a physician as "bilious" fever, "continued" fever, etc. In the same year the mortality reports include deaths from typhoid fever and enteric fever as though the two diseases were not identical. The later reports bear circumstantial evidence,

but no direct proof, that some reclassifications have been made by the health officer. Probably, however, the disappearance of "bilious" fever and the like from the mortality tables is largely due to improvement in the nomenclature used by the practicing physicians.

Finally, the author expresses a hope that other attempts will be made to broaden the studies of the relations between typhoid and the public health; that health officers and practicing physicians will devote themselves far more earnestly and intelligently than heretofore to the perfection of vital statistics, both in completeness and in classification; and that the city of Burlington will soon find some permanent means of improving the character of its water supply and, what is, perhaps, even more important, of introducing other sanitary reforms, all of which combined will result in the reduction of its typhoid, diarrheal, infantile, and total mortality to a figure appropriate for a city of its unsurpassed natural conditions.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 14, 1906.

The President, Prof. W. T. Sedgwick, in the chair.

The following members and guests were in attendance:

Members.

M. N. Baker, C. H. Baldwin, L. M. Bancroft, W. T. Barnes, G. W. Batchelder, J. E. Beals, E. M. Blake, George Bowers, E. C. Brooks, G. A. P. Bucknam, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, E. R. Dyer, H. P. Eddy, E. D. Eldredge, I. T. Farnham, J. N. Ferguson, Desmond FitzGerald, F. F. Forbes, D. W. French, T. C. Gleason, A. S. Glover, F. W. Gow, J. O. Hall, J. C. Hammond, Jr., L. M. Hastings, V. C. Hastings, H. G. Holden, J. L. Howard, E. W. Kent, Willard Kent, L. P. Kinnicutt, H. V. Macksey, D. E. Makepeace, A. D. Marble, A. E. Martin, W. E. Maybury, John Mayo, A. S. Merrill, F. E. Merrill, H. A. Miller, C. A. Mixer, Wm. Naylor, G. H. Palmer, W. W. Robertson, C. M. Saville, E. M. Shedd, C. W. Sherman, Sidney Smith, G. H. Snell, G. A. Stacy, J. T. Stevens, R. J. Thomas, H. L. Thomas, W. H. Thomas, W. H. Vaughn, R. S. Weston, J. C. Whitney, O. J. Whitney, I. S. Wood, C.-E. A. Winslow, G. E. Winslow, E. T. Wiswall. — 64.

Honorary Members.

W. T. Sedgwick, F. W. Shepperd. — 2.

Associates.

Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edw. F. Hughes; The Fairbanks Co., by F. A. Leavitt; Hersey Mfg. Co., by Albert S. Glover, Jas. A. Tilden, H. D. Winton, H. V. Macksey; International Steam Pump Co., by Samuel Harrison; Macleod & Co., by W. F. Stoddard; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by G. A. Caldwell; National Lead Co., by G. L. Whittemore and H. McConaghy; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey and F. W. Hawks; Rensselaer Mfg. Co., by F. S. Bates and C. L. Brown; A. P. Smith Mfg. Co., by F. N. Whitcomb; Thomson Meter Co., by Edward M. Shedd; Union Water Meter Co., by W. F. Hogan; United States Cast Iron Pipe & Foundry Co., by F. W. Nevins; R. D. Wood & Co., by Wm. F. Woodburn. — 24.

GUESTS.

Hon. Thomas Thompson, Mayor, New Bedford, Mass.; T. H. Dearing, M.D., Water Commissioner, Henry A. Monk, Clerk, and John Kelly, Water Commissioner, Braintree, Mass.; Clarence Goldsmith, Supt., North Andover, Mass.; C. W. Gilbert, Woburn, Mass.; R. R. Thomas, Quincy, Mass.; F. L. Clapp, Stoughton, Mass.; A. H. French, Brookline, Mass.; G. A. Sampson, Boston, Mass.; C. Story, H. M. McRae, G. H. Bryant, G. H. Hanley, G. E. Washburn; C. H. Rollins, Water Commissioner, Watertown, Mass. — 16.

[Names counted twice. — 4.]

After the dinner had been served, President Sedgwick called the company to order, and said:

"Death has invaded our membership since the last meeting and taken from us one of our vice-presidents, Mr. Frank A. Andrews, of Nashua, N. H.; and another member, Mr. T. W. Mann, of Holyoke, has also died. These events remind us that the association is always losing at one end and needs always to be gaining at the other; in other words, we must ever be on the lookout for new members to take the places of those who pass away. This association can do its best work only if it has a large and vigorous membership, provided, of course, that that membership is of the right quality. In the Executive Committee meeting to-day we have been discussing the advisability of adding steadily new and fit material to our membership. Let each one of us see to it that no man who ought to be a member goes on long without being proposed for membership The Executive Committee will be glad at any time to receive applications.

"The next meeting of the association will be the annual field-day meeting. For this plans are not yet fully matured, and the Executive Committee would be pleased if any members who have bright ideas as to proper 'stunts' to carry out on field day would communicate those ideas to the committee. In other words, the Executive Committee will welcome hints from all sources, — although they will not promise to adopt any of them.

"The first business in order is the election of new members, and I will ask the Secretary to read the names of candidates who have been passed and approved to-day by the Executive Committee."

The Secretary read the names of the following applicants for membership:

Ransom Rowe, Lynnfield, Mass., Water-Works Contractor; James A. Tilden, Hyde Park, Mass., Mechanical Engineer; George G. Honness, Katonah, West Chester County, N. Y., with the New York City Aqueduct Commission; Dabney H. Maury, Peoria, Ill., Consulting Engineer; Nicholas P. Simin, Moscow, Russia, Chief Engineer, Moscow Water Works; Francis F. Longley, Washington, D. C., engaged in water supply, water purification, and other engineering work.

On motion of Mr. Bancroft, the Secretary was directed to cast the ballot of the association in favor of the applicants, and they were declared elected.

THE PRESIDENT. Massachusetts is a state of cities, and among the cities that adorn the state and, as we believe, adorn New England, there are few more thriving or more prosperous than New Bedford. We are fortunate in having as one of our guests to-day the chief magistrate of that city, Mayor Thompson, who has kindly consented to say a word to us as members of the New England Water Works Association. I have great pleasure in presenting Mayor Thompson of New Bedford.

Mayor Thompson was received with hearty applause, and in response said:

Mr. Chairman and Gentlemen, — It is a pleasure for me to be here before such an intellectual body of men, especially as all are designated as being on the water wagon. [Laughter.]

New Bedford is a thriving city, and no doubt every one of you has read of some of the conditions which are surrounding the municipality of New Bedford. There are peculiarities that surround every municipality, and New Bedford is no exception, although we pride ourselves on being the first city in this great country in what we call the manufacture of fine goods. We have 42 cotton factories in New Bedford, with a capital stock of about $15 829 000. The amount of dividends paid last year was $829 500, or about 5.94 per cent. upon the money invested.

There is one thing that we had to do, and that was to increase the water rates to the manufacturing interests in New Bedford. It shouldn't have been done, but as they desired to have the water department upon a paying basis they placed from two and one-half cents a thousand gallons up to fifteen, making an addi-

tional expense to the cotton factories and the various other manufactories in New Bedford of about $65 000.

We are trying to put meters in to the best of our ability, but some man up here in our legislature, who is more conversant with crazy quilts than he is with meter systems, is trying to compel all municipalities in Massachusetts to meter every service and and to attach a penalty if you don't do it before a certain date.

Now, I think we citizens of Massachusetts have, to a degree, lost faith in our representatives and our senate, simply because we don't go around and look after these freak bills that are being presented to the legislature by interested people.

There is no doubt of it, there has been a peculiar situation in New Bedford. We have a license commission. The license commissioners are appointed by the mayor and controlled by the mayor. The license commissioners do not grant the licenses; they vote for them, that is all, but the mayor selects those who shall have the licenses and the commissioners simply concur. And why? Simply because when it comes up to a question of an election they want to have those fellows, because you know there is more profit in whiskey than there is in molasses, because when business is poor they can put the hose into the barrel and forget to take it out, and so when they can't get a percentage over the counter in any other way they can make it on the water, for we only charge $2.50 for a faucet. [Laughter.] So you see that, he having the control of that department, it is very easy for him to say when it comes election time to one of these men, "I should like to have $500 from you for the campaign fund." He says, "I can't afford to pay it." Put the pencil through his name; he can't have a license. But he don't want to go back and work in a sewer; he don't want to use a pick.

They tell a story down in New Bedford about a fellow who was down on the wharf looking at one of the old whalers, and his attention was attracted by a big anchor which was lying there. He stayed round so long that finally somebody asked him what he was waiting for. He replied, "I am waiting to see the man who uses that big pick." [Laughter.] Now, these fellows don't want to go out and work with a pick or a shovel; they know there is more profit in the liquor business. They know they can make

four or five thousand dollars a year, and for the chance to make it they are willing to pay that $500. The legislature of Massachusetts has placed that upon us by saying there shall be one license for every 1 000 people in a municipality, so New Bedford has about 74 licenses. And, of course, for years past we have been subjected to what you may call the pseudo-apothecary shop. It is patent medicines and Peruna alongside of nursing bottles and liver pads. Down cellar they make the goods and in the back shop they deliver up. [Laughter.]

And the municipality has been retrogressive along these lines and spending its money extravagantly, actually throwing it away; in the month of January, under the new overseers of the poor that I placed there, we saved $50 a day even in our poorhouse, and on the outside we saved $60 a day, making $110 a day, and without any real detriment to the municipality of New Bedford. But because of the former extravagance we were forced to saddle upon the manufacturers of the city of New Bedford $65 000, and then our water department receives the blame, because of the extravagance and the incompetency of the men who have handled the administration.

So I say to you men who are trying to give the people what will be beneficial to them, and to bring to the man bloom upon his cheek and not waste and take from the man or curb his physical or destroy his mental powers, that these men, who hold the reins of government through the power of liquor have simply subjected the water boards of Massachusetts to that condition of things, and it will happen in every municipality of Massachusetts, I care not which it is, unless we can arrest that condition that monopolizes man and makes him bow subservient to the selfish ambition of any man or any coterie of men. And if you men are alive to the situation of a progressive municipality you can take this thing in hand; and that is the paramount question to all other questions, because the water departments of this great state are proving to us the possibilities of municipal ownership in the near future, so that the car tracks and lighting and so forth shall come into the hands of the people in order that the people may have the revenues from what they consume and pay for. And if you men will only just clasp hands in one great chain

from the Berkshire Hills to old Cape Cod, you can give Massachusetts better legislation by sending better men to the legislature, who will enact laws that shall be beneficial to the great body of the citizens of Massachusetts, so that posterity can walk in a narrow path and climb the mountains in the future because we have fought and have educated them to fight for the solution of the great and complex questions that confront us in this great and growing country of ours. Gentlemen, I thank you. [Applause.]

THE PRESIDENT. Mayor Thompson has touched on many points of interest to water-works men, certainly on one which we can all subscribe to, and that is that in our municipalities not infrequently water boards have suffered because of extravagance or ill-advised efforts in other municipal directions. What is greatly needed is some wise supervision of all municipal affairs, so that the schools and the streets, the water department and all other departments shall have their just and proper share of funds. We are grateful to you, Mr. Mayor, for bringing up these points.

The principal paper of the day, gentlemen, will be by one of our own members, the distinguished associate editor of an important engineering paper, the *Engineering News*, and a gentleman whose activities range over a wide field. Mr. Baker is not only an expert on water and water supply, but he is the president of one of the best boards of health in the United States, the board of health of Montclair, N. J. I know of my own knowledge that this board has been more progressive, more scientific, more courageous, and more successful than almost any other local board of health of any place of equal size in the United States; and I believe that to be so largely because it has had upon it good physicians, good citizens, and especially a good engineer in the person of Mr. Baker.

This association has always been interested in sanitary questions, particularly as affecting water supplies. Many of you who have been connected with it as long as I have, or longer, have seen great changes in our attitude and in the attitude of the public toward water supplies, and some of you have heard in the past about the conditions at Burlington, Vt. Mr. Baker is thoroughly familiar with the conditions there, and especially with the modern conditions, and I esteem it a great privilege that we are to hear

from him this afternoon upon the water supply and certain sanitary matters connected with the water supply of Burlington.

It is a matter of regret that no representative, as far as I know, is present to-day from that city. We have members there, but Burlington is a long way off. We have had submitted, however, typewritten comments upon Mr. Baker's paper by some of the municipal authorities of Burlington, and also by some members of the association, especially Mr. Hazen of New York and Mr. Leighton of Washington. I will ask Mr. Baker to present his paper now, but we will postpone our discussion of it for a short time while we listen to a description of the pitometer, which has been set up here in the middle of the room, by Mr. Blake, and then we will have a discussion of Mr. Baker's paper and, if time permits, of Mr. Blake's. I have great pleasure in presenting Mr. Baker. [Applause.]

MR. M. N. BAKER. I wish to thank the President for the kind word which he has spoken of the Montclair Board of Health, because I am deeply interested in having the work of boards of health throughout the country entered upon with more vigor, and I therefore welcome every opportunity which calls attention to the efforts which we have made, in the hope that similar efforts may be made in other communities; for, I regret to say, to a large extent throughout the whole country the work of local boards of health is, considering the vital interests involved, in a very shameful condition indeed.

Mr. Baker then proceeded with the presentation of his paper, which was entitled "Water Supply, Typhoid Fever, and Diarrheal Diseases in Burlington, Vt., 1879 to 1905, Inclusive."

EDMUND M. BLAKE, civil engineer, of Boston, explained "The Pitometer and Its Uses"; after which there was a discussion of Mr. Baker's paper. First, a communication from Dr. B. H. Stone, director of the State Laboratory of Hygiene at Burlington, Vt., was read by Mr. Coggeshall. Mr. Robert S. Weston, Mr. C.-E. A. Winslow and Prof. Leonard P. Kinnicutt participated in the oral discussion which followed, and papers by Mr. Allen Hazen and Mr. M. O. Leighton were presented.

On motion of Mr. Bowers the meeting adjourned.

EXECUTIVE COMMITTEE.

TREMONT TEMPLE, March 14, 1906.

Present: President William T. Sedgwick, R. J. Thomas, F. W. Gow, F. E. Merrill, L. M. Bancroft, Charles W. Sherman, John C. Chase, Willard Kent.

Six applications for membership were received and approved, *viz.*, Ransom Rowe, George G. Honness, Dabney H. Maury, James A. Tilden, Nicholas P. Simin, and Francis Fielding Longley.

On motion of Mr. Sherman, seconded by Mr. Thomas, the following ruling was unanimously adopted: "That applications for admission as members may be received from persons otherwise eligible, engaged in a technical capacity with firms dealing in, or manufacturing, water-works supplies, provided the said firms are already Associates."

Voted: That the President, Mr. Stacy, and Mr. Merrill, be a committee on the June Field Day with full powers, including that of adding additional members.

Voted: That the above committee be also a committee on the Annual Convention.

Voted: That, as an experiment, the tabulation of water-works statistics be omitted from the JOURNAL for the present year, but published next year and thereafter biennially.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Thomas W. Mann, civil engineer, of Holyoke, Mass., died in that city on February 28, 1906.

Mr. Mann was born in Ireland about sixty years ago and came to this country when ten years of age, with his parents, who settled in Holyoke. After graduating from the Holyoke High School he received an appointment to West Point, but failed to pass the physical examination. He then took up civil engineering, and for some years he was employed by the Holyoke Water Power Company; later he opened an office for himself, which he maintained for some twenty-five years. He was town engineer of Holyoke before it became a city, and was city engineer in 1884 and 1885.

He became a member of the New England Water Works Association on June 9, 1892.

Frank Albert Andrews, assistant superintendent of the Pennichuck Water Works, Nashua, N. H., and one of the vice-presidents of the New England Water Works Association, died on March 1, 1906.

Mr. Andrews was born in Nashua, August 3, 1865. He had been with the water company for twenty years, and had been assistant superintendent for several years.

In addition, he was a member of the insurance firm of Andrews, Son & Co., and was an officer of several corporations. A local paper says of him:

"Mr. Andrews was one of the sunniest of the active young men of the city. He was upright and in the open in all his business transactions, and in the social circles of those of his own age no man was more highly regarded as being unselfish and determined on doing all he could discover to do to add to the happiness of those with whom he was associated."

He was elected a member of the association on December 14, 1887.

JOHN JAMES ROBERTSON CROES, one of the most widely known civil and hydraulic engineers of this country, died March 17, 1906. Mr. Croes was a past president of the American Society of Civil Engineers, and an honorary member of the New England Water Works Association.

Mr. Croes was born in Richmond, Va., November 25, 1834. His early boyhood was passed in Terre Haute, Ind., and he was educated in the College of St. James, Hagerstown, Md., graduating in 1853. He then took up the study of civil engineering in the offices of practising engineers. He was employed on the Brooklyn Water Works, the New York Water Works, and the Washington Aqueduct; and then, after a short service under James P. Kirkwood on investigations relating to St. Louis and Cincinnati water works, returned, in 1865, to New York to take charge of surveys for storage reservoirs in the Croton valley. He was connected with the Croton Works for a number of years, and later with the New York Department of Parks. During the last twenty-five years he had been connected as chief engineer or consulting engineer with many important engineering enterprises.

Mr. Croes became a member of this association June 17, 1887, and on September 14, 1904, was made an honorary member.

BOOK NOTICE.

HYDRAULIC MOTORS. By Irving P. Church, M.C.E., Professor of Applied Mechanics and Hydraulics, Cornell University. New York: John Wiley & Sons. 1905. ix + 280 pages. 6 × 9 inches. Price, $2.00.

This excellent book has been prepared as a text-book to be used by students already well-grounded in the principles of mechanics and hydraulics. It is particularly adapted for use after Professor Church's "Mechanics of Engineering," to which it may be considered supplementary. Mathematics are used freely. Like all of Professor Church's writings, the reasoning is clear and logical, and the explanations are excellent.

The titles of the chapters are: Chapter I, General Considerations and Principal Types of Motors; Chapter II, Gravity Motors; Chapter III, Preliminary Theorems fundamental to the Theory of Turbines and Centrifugal Pumps; Chapter IV, Impulse Wheels; Chapter V, Turbines and Reaction Wheels; Chapter VI, Testing and Regulation of Turbines; Chapter VII, Centrifugal and "Turbine" Pumps; Chapter VIII, Pipes, Weirs, and Open Channels; Chapter IX, Pressure-Engine, Accumulators, and Hydraulic Rams; Appendix, Diagrams and Tables.

The several types of wheels are illustrated both diagrammatically and by views of actual wheels. Among the views are a number of excellent half-tone plates of some of the very large recent wheels.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XX. September, 1906. No. 3

This Association, as a body, is not responsible for the statements or opinions of any of its members.

PROGRESS REPORT OF THE COMMITTEE ON METER RATES.

BY THE COMMITTEE.

[Presented September 12, 1906.]

The Committee on Meter Rates is gratified that the discussion upon its report* has been so general and so intelligent. The fact that its suggestions have been favorably criticised in some instances and unfavorably in others, shows that the conditions under which meters are installed vary to a great extent in different places, and the subject presents itself in different ways to different people.

In replying to some of the suggestions and criticisms brought out by its report upon meter rates, the committee does it in no spirit of antagonism to the suggestions or plans proposed. It seems desirable that all points should be discussed, and the advantages of any proposal, or the objections to its adoption, emphasized.

Mr. Herschel in his discussion of the matter suggests, or seems to suggest, that the part of the annual cost of a system of water works which is due to the provision of large capacity standing ready for service should be met by a charge for fire service, and that the balance be met by a charge for water actually used. This is an excellent suggestion, and is only another way of doing what the committee suggests, namely, meeting fixed charges by an assessment, or appropriation, which is independent of the amount of water used. The committee agrees with him that this should

*Presented September 13, 1905, and published in the JOURNAL, September, 1905, p. 322.

be paid out of the tax levy, and it furthermore believes that an equitable proportion of the entire annual maintenance expenses to be raised in this way would approximate one half. Unfortunately, however, the prevailing idea seems to be to keep this appropriation for the tax levy as small as possible, and, as the revenue from consumers increases, to eliminate it entirely, rather than to relieve the consumer by reducing the rates, as equity between consumer and taxpayer certainly demands. As practical men, we must advocate practical measures, and however desirable it is that there should be a more equitable arrangement between the consumer and taxpayer than now exists, the committee feels that it is more feasible in the present state of things for the department to take what can be had from the tax levy, as proposed by it, applying it to the payment of fixed charges, and raise the balance for meeting those charges by an assessment of some kind, than to endeavor to convert municipal governments to the idea of appropriating an adequate amount for fire protection. The taxpayer probably has greater influence with the city council than the consumer has.

After the charges for "standing ready" are met, the water furnished can be paid for upon the basis of the actual quantity used, as both Mr. Herschel and the committee agree. The committee, however, does not agree with Mr. Herschel "that to attain simplicity is reason enough to reject the committee's plan of front-foot assessment." It does not consider the front-foot plan as a complicated method, but, on the contrary, as a simple one, and the difficulty of adoption is not on account of its complexity, but on account of its newness, or because it is different from any method now in use. Mr. Herschel regrets that the committee— in saying, "If the first system (gravity system) has an ample supply, it costs no more (within certain limits) to furnish a large amount of water than a small one" —"gives renewed currency to an exploded fallacy." The statement of the committee is certainly a fact, and if, as Mr. Herschel says, it is an "exploded fallacy," it is, we presume, so much the worse for the fact. If the remainder of the committee's remarks upon this subject are examined, it will be seen that it draws no unwarrantable conclusions from the above guarded statement.

In regard to the question of favoritism to manufacturers, which Mr. Herschel raises, that is the very thing that the proposition of the committee avoids, or at least seeks to avoid. A sliding scale may or may not be favoritism, but a plan to make all consumers, or property owners, pay their proportional part (however it may be ascertained) of the charges due to "standing ready," and then pay a uniform sum per unit for water actually used, is as far removed from favoritism as any plan can well be. It is not specially in the interest of manufacturers that the plan is proposed, but in the interest of the water department, which will surely be benefited by a method of supplying water equitably to large and small consumers. It is undoubtedly to the advantage of the community as a whole that both domestic and business consumers should have all the water of which they can make a legitimate and profitable use, as well as that all waste should be stopped.

The committee has referred in its report to the difficulties in the way of adjustment of the revenue attendant in many places upon a strictly metered rate without a minimum charge of some kind, a subject which Mr. Herschel altogether ignores, *and one which must be considered.* He lays great stress upon the equitable method of charging, and says that to him there is but one simple way, — "to charge by the quantity used or wasted that is consumed on the premises." Is it equitable that a house that occupies a large lot of land, with plumbing fixtures for a luxurious use of water, and occupied by a small family, should pay a very small sum, simply because it uses little water, while the cost of the entire system is increased by the length and size of pipe and other elements of construction, necessary to "stand ready" to supply such a house? Is it not more equitable that a sum should be paid to meet the fixed charges on the construction, whether a large or small amount of water is used? On the other hand, if a house is on a small lot, and has but one faucet, why should not the sum for fixed charges be paid, and in addition a sum for a large amount of water (used only through one faucet and consequently at a slow rate and not requiring large street piping, etc.) at a rate representing the actual cost of collecting and delivering the water, exclusive of fixed charges? It may be said that this is a different

method from that used in selling gas and electricity. This is true, but it does not differ more than the conditions. Fixed charges do not constitute so important an item in the latter cases. The cost of the plant is not so large in proportion to the value of the product. Labor and material enter into the cost of gas and electricity to a larger extent than into the cost of water, the actual cost of which is usually very small; the items of coal and salaries being almost the only items that vary with the amount of water used, assuming that the plant is of sufficient size. The size of the piping is dependent more upon the need of fire service than upon the consumption of water, especially in the smaller places.

Electric and gas companies do, however, often make a minimum charge. This charge in some places is one dollar per month, which must be paid if no lamp is lighted.

The committee feel that an insistence upon the principle that *all* charges for water must be strictly upon the amount *used* will do more to prevent the use of meters than any other one thing, and that a minimum, or a separate, rate to meet fixed charges is an absolute necessity of a meter system in most places.

Mr. Hazen put the argument of the committee in a very effective form in the early part of his discussion. The Cleveland plan, as described by Mr. Bemis, is practically the same as the committee's plan for a " multiple minimum " method, but worked out on a different basis than the Merrimac rates, which were given in the report as an example of the method in actual use, and which were designed about the time the Cleveland plan was adopted. The fact that the origins of these essentially similar plans were entirely independent suggests that there may be merit in this method for meeting certain prevailing conditions.

The committee, after carefully considering the discussion, is still of the opinion that it is in most cases absolutely necessary to have a minimum in some form, or to have a rate composed of two elements; one of which represents the fixed charges of the system, or the fair cost of " standing ready," and which must be paid independently of the amount of water used; and the other, for the water used or wasted.

It also feels that it is unessential upon what basis the rate for fixed charges is determined, so that it is independent of the

amount of water used, and approximately represents the comparative benefit that is rendered to any particular piece of property. It may be, as suggested in the report, upon frontage, which seems a fair and available measure, or it may be upon the assessed value of the property.

The committee fully recognizes the unsatisfactory condition in which the fire service question stands in respect to the amount which shall be paid for it, and makes the following suggestion, which it believes could be adopted by either a municipality or private water company (except that vacant land and unserved houses could not be assessed by the latter), and that it would be an equitable and feasible solution of the question of the charge for fire protection.

Make no charge to the city, or appropriation from the tax levy, for fire protection, but collect from all property upon the pipe line (with the above exception) a sum representing the fixed charges of the system based upon the assessed value of the property as taken from the assessors' books. This sum may amount to approximately one half of the total annual expenses of the water works, including interest and sinking fund. The remainder of the annual expenses will be collected for the use of water, and strictly in accordance with the amount used. The result of this will be that all property on the pipe lines will pay for fire protection, as it should, and no property off the pipe lines will make any such payment. Vacant land and houses not taking water will pay in proportion to their value, as they should, for the benefit received on account of the existence of the line and the consequent enhanced value. It is probable that this class of property must be omitted from the assessment in the case of water companies.

This plan will provide that the cost of fire service be paid by property that is benefited; that the water shall be paid for in proportion to the *quantity used*; will allow, if desirable, that the unit price of water shall be uniform to large and small users; that an intelligent estimate of the relation of revenue to expense can be made, and that there will be no serious excess or deficit under the existing rates, and without making any increase in general taxation for city purposes. It will be practically the assessment

method of the committee's report, except that it substitutes assessed values for frontage and eliminates the question of raising funds for fire purposes by the ordinary tax levy; it provides that property shall pay for the benefit it receives, and that consumers shall pay the cost of what they receive. It recognizes the fact that property owners and water consumers are not identical, and may or may not be the same persons; and the committee suggests it as an alternative method with some advantages that the frontage plan does not have. This method also meets a frequent and valid objection that is raised by that part of the population of towns outside of the district actually served by the water supply, namely, against being taxed for improvements in which they do not share. It would obviate the necessity of forming a fire district inside of the town itself, which has been done in so many instances in order to avoid the opposition of outside taxpayers to the installation of needed water supply systems.

As an example of the working of such a system, suppose a house with modern plumbing, paying under fixture rates \$20 per annum, has an assessed valuation of \$5 000 for house and lot. Assume that a general change to meter rates is contemplated, as a check to waste of water (the only real object of the use of meters), and that it is important that there shall be no reduction in the revenue received. Assume also that it is found, after investigation, that in this place, one half of the annual expense, including interest and sinking fund charges, is due to the element of "standing ready" and for fire protection. Then \$10 should be raised by a sum computed on the assessed value of the property. In this case the rate would be two tenths of one per cent., or \$2 on a thousand of the assessed valuation, which, of course, would be the rate for all of the property in this place.

The remainder of the sum that this property should pay for water service, or \$10 per year, would be raised by meter rates on the water actually used or wasted and at a rate approximately one half as great as rates that would meet the entire expense. The house in the above example, although having all of the advantages of modern water service, might under the ordinary meter rates, with no minimum charge, by a prudent use of water, pay not more than \$7 or \$8 per annum, which would reduce the

revenue of the works and not be a fair equivalent for the service it receives.

A less valuable house would not pay so much for the "standing ready" element and fire protection, but would pay for all of the water that it used.

In closing its report at this time, the committee wishes to repeat that it still considers its suggestions as suggestions only, but that the discussion and further study of the subject emphasizes its conviction that, in general, a method of meter rates, to be satisfactory, must include some charge for "standing ready" that is entirely independent of the amount of water used, whether the same is one minimum, several minimum charges, or an assessment in some form.

The subject is still open; much must yet be learned by experience. The committee hopes discussion will go on and further data be submitted by members of the association from time to time, to the end that in so important a matter the present uncertainty in opinion and practice may give place to some definite principles of action.

FREEMAN C. COFFIN,
FRANK E. MERRILL,
C. M. SAVILLE,
H. V. MACKSEY,
CHARLES F. KNOWLTON,
Committee.

A HOMESPUN DEVICE FOR RAISING PIPE IN THE TRENCH.

BY JOSEPH E. BEALS, SUPERINTENDENT OF WATER WORKS, MIDDLEBORO, MASS.

[*Read September, 14, 1906.*]

When making some suggestions as to the practical side of our work as an association, the question was asked if I would present a paper at this meeting. In an unguarded moment, I assented, and hastily gave as a subject that named in the program. I propose to enlarge upon that subject somewhat, and give some bits of experience in raising and in lowering pipe.

In presenting this paper I shall make no pretension to literary merit, but propose to tell as plainly as I can how I accomplished some things on which I had no previous instruction and knew of no precedent to follow.

In the course of events the authorities of the town decided to lower some four or five hundred feet of street which passed over a knoll. The new grade would leave our pipe dangerously near the surface, and we decided that it must be lowered. The problem for us was, how to do it and keep the supply of water on all the time. About all the instruction we could get was that the way to do it, was — to do it. Following the line of the pipe we dug out the old trench down to the pipe, digging it rather wide, and then dug down beside and under the pipe to the depth at which we wished the pipe to lie, leaving bridges across the trench under the pipe just back of the bell ends, on which the pipe rested until we were ready to lower it. We then went back and forth along the trench lowering each bridge just a little, and, after a little coaxing, the pipe just lowered itself. For want of any better knowledge we have since lowered another section in the same way.

At another time our town authorities had decreed that a certain section of street across a valley for a distance of some four hundred feet should be raised. As this would put our pipe to an

undesirable depth we decided that the pipe should be raised. The problem with us was,—how to do it. And it is OUR solution of the problem that gives the title to this paper. Somebody had presented a paper before this association describing a method of raising pipe by means of a series of screws. As a set of screws sufficient to do the work would cost more than the pipe was worth, we considered that, while the plan was an elegant one from an engineer's standpoint, it would be cheaper for us to throw the pipe away than to try that method. We then planned to do it by putting a derrick over the pipe and with a differential chain pulley raise it a little at each joint, going back and forth. This was too slow. The men did not feel as if they were accomplishing anything. We had some men in our gang who had worked in a railroad track gang and knew the power of a claw-bar. We borrowed such a bar and railroad tamping iron. We took two pieces of 4 x 6 timber some six or seven feet long, and placing them about two inches apart, nailed a piece of board across the timbers on the upper and under side at each end. We had a short-linked log or timber chain on the job, and dropping the chain down between the timbers, we hooked it around the pipe and, bringing it up above the double skid and engaging the claw of the bar across one of the links and between two others, with a block of wood or timber across the skids for a fulcrum, we obtained a strong, powerful purchase, and as the long end of the bar went down the pipe came up with an ease that astonished us. Here, then, we had an apparatus that was easy to handle, quick to apply and powerful in its action. Four men made a full gang to raise the pipe,—one man in the trench to take along the chain and hook it around the pipe, two men to take along the skids and be ready with their shovels to fill under the pipe as raised, and one man with the claw-bar and block of wood for the fulcrum. In this way we raised some three or four hundred feet of pipe, some of it as much as four feet, in a very short time. I should have said that the pipe raised and lowered was six inch. In both cases we had our calking tools ready, and if the joints showed signs of weeping or spurting a few strokes of the hammer would stop it, and when the pipe was raised or lowered to its position every joint was inspected and driven up as needed before covering.

We were a little afraid that when the pipe was changed from a curved line to a straight line the joints would be inclined to buckle, and dug the trench rather wide so that if necessary the vertical curve could be changed to a lateral curve, but we found in each instance that the pipe settled into a first-rate straight line.

There was one hydrant on the line of pipe raised. This we raised by placing our derrick over it and, with a chain pulley, raising it as we raised the pipe. We raised it about three feet, keeping it ready for service all the time.

The pipe came up so easily and settled so finely into its new position, that we felt that we had found a simple method to do a difficult job and that the experience might be worth the telling. If the idea is new the credit for it is due to the man in the trench.

If this paper shall draw out some one who has done the same thing or something better, or if it shall call out any questions, one of my objects in presenting it will be accomplished.

EXPERIENCES IN INTRODUCING COMPULSORY METERAGE, AND RESULTS OBTAINED BY METERING ALL SUPPLIES IN THE TOWN OF BROOKLINE, MASSACHUSETTS.

BY F. F. FORBES, SUPERINTENDENT OF WATER WORKS, BROOKLINE, MASS.

[*Read September 14, 1906.*]

The title of this paper is somewhat misleading, for, as you all probably know, Brookline is a town, working under a town form of government, although it has a population of about twenty-five thousand to-day, and a valuation exceeding $93 000 000; consequently, all acts of the town must be made in open town meeting in which every legal voter can take part, and the majority vote must prevail.

I think that it reflects great credit on the intelligence and public spirit of the citizens, to vote as they did almost unanimously in favor of metering all supplies, both public and private, as recommended by a committee appointed by the town to look into and report on this matter.

On December 28, 1904,— at the time the vote for a universal meter system was adopted,— about 2 225 meters were in use, metering more than half of the supplies. At the end of July, 1905, every service not shut off, whether public or private, was supplied with a meter, and the number of meters, including elevator counters, had increased to 3 893.

Very little opposition was made by the water takers to the installation of meters on their premises. As might be expected, some feared that the water rates would be much increased, and that they would lose the feeling of freedom in the use of water which they had formerly enjoyed. I think there was one case only, where the owner positively refused to have a meter set on the premises, and in fact the whole work went along more smoothly and with less opposition than was expected.

The introduction of meters resulted in causing a great deal

of poor plumbing to be overhauled or torn out completely, and replaced by more modern and better fixtures. The results to the town have been most satisfactory. Considerably less water has been pumped and the revenue has not been decreased, although the books show about $2 000 less collected for the year ending February 1, 1906, than for the preceding year; but this difference is fully explained by the fact that meter rates are not due until the water has been used, whereas fixture rates were payable in advance. Brookline sends no bills until the water has been used.

The town was so well pleased with the results of the universal meter system, that the price of metered water was reduced from fifteen cents per hundred cubic feet to twelve cents for the same amount, a reduction of twenty per cent.

The table which follows shows the effect meters have had in controlling the consumption of water, and leakage through faulty fixtures.

Year.	Population.	Consumption for First 7 months.	Amount of water passing from the reservoir for 24 hours calculated from the rate of flow between the hours of 12 and 4 A.M. for month of August.
		Gallons.	Gallons.
1897	17 000	289 084 197	517 256
1898	17 500	326 275 813	587 780
1899	19 000	392 478 758	592 178
1900	21 500	418 195 714	691 012
1901	22 000	410 635 002	688 625
1902	22 500	422 059 769	644 164
1903	23 000	457 636 465	724 334
1904	23 500	507 438 066	858 831
1905	24 000	513 564 018	617 535
1906	24 500	425 864 505	562 992

It will be seen from the above table that the average amount of water leaving the reservoir between 12 and 4 A.M., for the month of August, 1906, with a population of 25 000, was less than the amount during August, 1898, with a population of 17 500. No leaks of any account have been found in any part of the distribution, and this smaller waste is due to the better care which has been taken of the water fixtures, and the controlling of un-

necessary use: by unnecessary, I mean the water which was allowed to run in winter to prevent freezing, and in summer to cool milk and other articles of diet.

The greatest trouble with excessive water bills occurred in tenement houses of the poorer class, where one meter often supplied four or more families. The tenants perhaps failed to promptly notify the landlord of leaks, or were themselves ignorant of any defects in the plumbing. It often happened that owners of property were non-residents, and consequently not easy to reach. The bills in some cases were several times the regular fixture charges. I am glad to say, however, that these large bills are growing less in number.

From a careful study on the part of the writer, it is very evident that the people of Brookline can use all the water that modern sanitary practice requires without stint, and not have bills in excess of the regular fixture charges, provided that the plumbing is kept in order and the water not allowed to run except for legitimate use. So far, no evidence has been found that the sewers and drains are not as clean as they were before the introduction of meters.

Some of the details of setting meters are as follows:

All the meters for *drinking fountains* are placed in boxes in the ground.

A good deal of time was given to the study of the best way of metering the *water-cart hydrants*. It was not considered safe to place the meters on the water-cart hydrants, as street watering in Brookline is continued long after freezing weather sets in. The plan adopted was to set a two-inch Gem meter, which is sure to drain, in a special cast-iron box, twenty inches in diameter and thirty inches deep, placed in the sidewalk near to the post. The meters can be easily read, and removed for test and repairs.

A larger part of the *house meters* were set in cellars, and boxed where in danger of freezing. All meters are so set that they are easily interchangeable with any other make of the same size. The cost of setting meters varied in different houses, but, as a general thing, a man and helper set from eight to ten meters per day.

A few words in relation to the maintenance and care of meters:

Our experience shows that it costs less to read and change meters than it did to inspect the water fixtures and see that the regulations governing the use of hose, etc., were properly observed. It is our custom to so plan our work that the reading can be done by our regular men. It has always been our policy to keep the meters in good repair so that they shall measure the water accurately as long as they are in service. We do not wait for a meter to break down or wear out. Once each year we look over the record of all meters carefully, and if there is any indication or even a suspicion that the meter is registering less than it should, it is taken out and tested, and repaired if necessary. When a $\frac{5}{8}$-inch meter has registered one hundred thousand cubic feet, it is removed and thoroughly repaired, even though it appears to be in good condition.

We believe that it is better for a town or city to keep the meters in the highest state of accuracy for two reasons; first, the revenue will be larger, and, second, there will be less trouble in the collection of the bills. It is a fact, strange as it may seem, that the water taker will always consider the smallest bill received as the correct one, and consequently, if a bill becomes small owing to a failure of the meter to measure all the water passing through it, it will form the basis of comparison with the bills which follow and which justly charge for the quantity of water used, and no amount of explanation will quite convince the taker that he is not paying more than he should.

The per capita rate of Brookline is large, owing to the great amount of water used on several large estates where comparatively few people live, and by the town in its various public buildings, and for watering streets. The per cent. of metered water used by the town for the last six months of 1905 amounted to 20.7 per cent., or fifteen gallons per capita for a population of 25 000. During the above period of time the meters accounted for all except 14 per cent. of the water pumped.

Tables which are annexed were taken from the report of the Water Board for the year ending January 31, 1906, and show in detail the amount of water pumped and consumed in connection with the public and private service for the six months from June 15 to December 15, 1905:

Summary of Water Recorded by Meter from June 15, 1905, to December 1, 1905, and Water Pumped during the Same Time.

Total number of gallons of water recorded by meters in private buildings	247 610 902	
Total number of gallons of water recorded by meters in public buildings and in public places	59 945 250	
Water used for flushing sewers, mains and hydrants; used at fires, by steam rollers, for puddling trenches of the sewer department, water department, Telephone Company, and flooding playground	5 062 500	
Total	312 618 652	
Total water pumped during this time	363 666 737	
Water not accounted for	51 048 085	
Per cent. not accounted for		14.0
Per cent. of metered water used by the town		20.7
Per cent. of metered water used by private consumers		79.3

Detail of Water Used by the Town.

	Gallons.
Bath house	10 066 500
Miscellaneous public buildings	1 011 000
Fire Department building	604 500
Public schools	5 623 750
Street Department	146 250
Water Department	5 527 500
Drinking fountains	1 120 500
Watering streets	32 840 250
Flushing sewers, mains, hydrants, fires, steam rollers, puddling trenches, and flooding playgrounds	5 062 500
Total	65 002 750

WATER SUPPLY PROBLEMS ON THE ISTHMUS.

BY CARLETON E. DAVIS, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY, CITY OF NEW YORK.

[*Read September 12, 1906.*]

Among the assets of the French Panama Canal Company which were turned over to the United States for the $40 000 000 purchase price of all rights and properties, were about 2 500 buildings of one kind or another. These were clustered in camps along the entire line of the canal, from La Boca at the Pacific end to Cristobal at the Atlantic end.

The French showed good judgment in locating these camps. High ground was selected if possible, where natural drainage was good, and where the refreshing winds that prevail through a large part of the year would have free play. No finer location could be found than that of Ancon Hospital on the side of the hill overlooking the city and Bay of Panama; while Cristobal, with its avenues of palm-trees, and the surf from the Caribbean, has a wonderful charm.

All the larger camps had more or less of a water supply. The more important houses had shower baths attached; the Ferdinand de Lesseps house at Bas Obispo had a swimming pool annexed; Ancon Hospital, and the Charles de Lesseps house at Cristobal, had bath tubs and water-closets. But all plumbing work was rather crude and clumsy according to our present ideas, and the general run of the houses were supplied with water from outside hydrants only.

The amount of water furnished was small. In some cases a gravity supply from springs was obtained, but in general, water was pumped from the nearest brook or river.

These water works were installed in the larger camps; but every camp, great and small, and every building, whether house, storehouse, or shop, had tanks for collecting rain water from the roof, and every tank was a mosquito breeder.

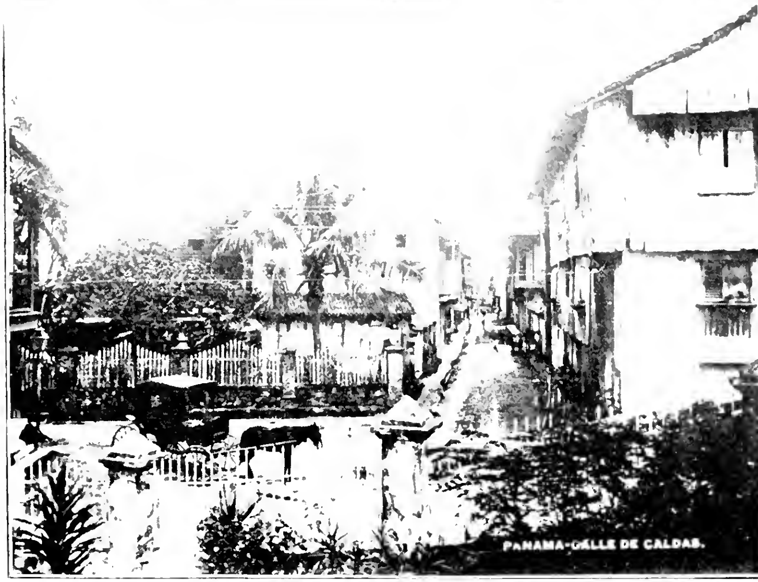

FIG. 1. TYPICAL STREET IN PANAMA.

FIG. 2. SANTA ANA PLAZA, PANAMA.

Plans of the various camps existed and were turned over to the Canal Commission with the rest of the French property. The water works were shown on these plans with a fair degree of accuracy.

Not much of the French property was of any permanent value. The machinery was obsolete. The buildings had been eaten up by ants and rot, and had to be practically rebuilt; and the water works could, at the best, be patched up for temporary use only.

The French record of mortality at Panama is well known. The Americans have found the Isthmus a reasonably healthy place. This change is due to the advance in the knowledge of tropical medicine, and to the full control which the United States has obtained through its treaty with Panama.

The French were handicapped. Even if they had had the knowledge of the causes and means of prevention of malaria and yellow fever which science possesses to-day, they would have lacked the power to enforce proper precautions. Their concession gave them no police authority, and even in the United States it appears that health regulations must sometimes be backed up by physical force in order to be effective.

The treaty between the United States and Panama gives the former full sovereignty over the Canal Zone, a strip extending five miles each side of the canal, excepting the cities of Panama and Colon; and in these cities, while sovereignty is reserved, the United States is given control of quarantine and health matters. The treaty further provides that the United States shall install water and sewerage systems in Panama and Colon, and stipulates that water and sewer rates shall be collected sufficient for the amortization of their cost, principal and interest, in fifty years.

Panama City, when the United States took over the canal, had from 15 000 to 20 000 inhabitants. The buildings varied from the rather imposing cathedrals down to little 8 x 10 shacks and palm-leaf huts. The streets were narrow, though fairly well laid out, on an approximately rectangular system. The principal streets were poorly paved with small, round cobbles. There was an electric-light plant, and a ten-ton ice plant, both of which were in operation at intervals. There had been an electric railroad and a gas works. There were a few drains, some of them very

old, but the city had never had a public water supply. The inhabitants depended entirely upon rain water collected in tanks and cisterns, and upon a few wells on the outskirts of the town. Water was sold from house to house at one cent gold per gallon. At the height of the dry season, when cisterns and tanks were exhausted and the wells were low, considerable actual suffering for lack of water frequently occurred among the poorer classes.

Colon, a city of 7 000 or 8 000 inhabitants, was formerly called Aspinwall, but its reputation for health was so bad that its name was changed. It was the Atlantic terminus of the Panama railroad, and except for this it had no particular reason for existence. The island of Manzanillo, on which it was built, was only a foot or two above sea level, and at high tide all the back streets were more or less flooded. The general aspect of the place was anything but prepossessing, although some of the railroad buildings on the water front were very attractive.

The Panama railroad had at Colon a water supply of 60 000 to 70 000 gallons per day capacity, collected from a small watershed at Monkey Hill. This was sufficient, however, only for the needs of the railroad and steamships. The general population of the city depended upon rain water, as at Panama.

The interest of the Canal Commission in the condition of these two cities of Panama and Colon was vital. The two chief diseases with which the French had to contend were yellow fever and malaria, both of which are transmitted chiefly, if not wholly, by the bite of infected mosquitoes. Eliminate these mosquitoes, and yellow fever and malaria will disappear.

The stegomyia, or yellow fever mosquito, breeds principally in clear water, and finds ideal conditions in tanks, cisterns, gutters, etc. The anopheles, or malarial mosquito, prefers swampy water.

The city of Panama was feared as the yellow fever center and the point from which cases would spread along the Zone. Not many cases existed when the Americans first went there, for the reason that the population had become largely immune. There were enough non-immunes, however, coming in from time to time, to keep up the succession of infected mosquitoes, and a case of yellow fever was imported every little while from Guayaquil or some other South American port. With the advent to the city

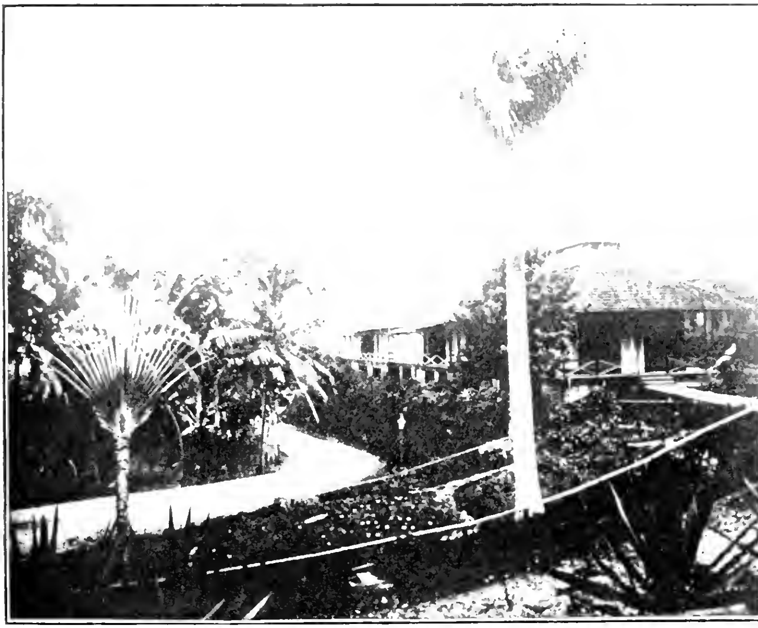

Fig. 1. Ancon Hospital.

Fig. 2. Palm Avenue, Cristobal.

of large numbers of non-immune Americans, canal employees and others, there was nothing to prevent a most serious outbreak of yellow fever, unless the mosquitoes could be suppressed.

And conditions in Panama were particularly favorable for the breeding of the stegomyia. With water at one cent a gallon, the Panamanian looked on the water man as his enemy and a rain storm as a blessing. Naturally, every receptacle a family possessed would be filled with rain water at each storm. This water was carefully saved for use, meanwhile serving the mosquitoes' wants admirably. Regular tanks and cisterns could be screened to a certain extent; but no inspection, however rigid, could stop this practice of a whole city, until there should be a public supply, making it easier to get fresh water for each domestic need than to store it.

The same reasons, though perhaps in a less degree, made it necessary to abolish all rain-water receptacles along the line of the canal and at Colon. Panama, from its large population and close commercial intercourse with South American ports, was looked upon as the most probable originator and distributor of yellow fever. But even if cases should occur there and get out along the line, the fever could not spread if the stegomyia had been destroyed.

Water supplies, then, over the entire isthmus were very essential from their indirect relation to the extermination of the stegomyia and yellow fever, in addition to the usual necessity existing for an uncontaminated supply for the thousands of canal employees that would be required. In the tropics, moreover, liberal facilities for bathing should be looked upon as a good investment from a business standpoint alone.

Water would be needed also for mechanical purposes as well as for domestic uses, for steam shovels, locomotives, and drills, and for fire protection.

The necessity of these water supplies as an important feature of the general sanitary improvement of the isthmus was recognized from the outset by those in authority, and they were provided for in the treaty with Panama as mentioned above. The Isthmian Canal Commission made them one of the matters of first consideration upon their taking over the work from the French.

The French company, pending the sale and transfer of their property, had not stopped work; though they had continued it with an organization and force only sufficient to prevent the lapsing of their concession. The transfer was made from the French to Major Black of the Army Engineers, representing the United States, and the old canal organization was carried on by Major Black until the chief engineer, Mr. Wallace, and the chief sanitary officer, Colonel Gorgas, reached the isthmus, the latter part of June, 1904. The engineers in charge of water works and sewers, under the direction of the writer, reached Panama three weeks later.

The Isthmus of Panama, like all Central American countries, is of volcanic origin. At the line of the canal it is about fifty miles wide from ocean to ocean. Along the Atlantic coast there is a margin ten or fifteen miles wide not greatly above the sea level, but in general the country is hilly, the divide lying about ten miles from the Pacific coast, and reaching a height of six hundred or seven hundred feet. Large masses of basalt are found, in addition to softer varieties of rock. Clay is the predominant earth.

Rainfall varies from sixty inches on the Pacific coast to one hundred and thirty inches on the Atlantic coast, being about ninety inches at Culebra on the divide. The year is divided into wet and dry seasons. As a rule, the former begins in the month of May and continues till December, when the dry season sets in and lasts practically without rainfall for four or five months.

Streams are numerous. As might be expected from the amount of rainfall and the nature of the country, they are often very turbid in the wet season. In the dry season they are clear and have only slight color.

The water works for the city of Panama were taken up first and pushed in advance of any others. It was estimated that the city would have a future population of thirty thousand. There is no manufacturing in Panama now, and probably never will be. The character and habits of the population are such that a large consumption of water need not be expected. Two million gallons per day, or about sixty gallons per capita, was taken as the necessary amount to supply.

Some years previous a franchise had been secured by a private

company for the introduction of water, but one of the periodical revolutions had stopped proceedings before construction had more than begun. This company had planned to take water from the Juan Diaz River, about fifteen miles east of the city, — an excellent source. But the property holdings of the local owners of the old water company, and other practical reasons, prevented the serious consideration of this source for the new works.

A ground water supply was considered, but the volcanic origin of the country was not favorable to underground water. Some investigations were made without results. Borings made for the canal work proper had not indicated the presence of a supply of water, except near Colon, where salt water was found.

Final selection was made of the Rio Grande at a point about ten miles from the city, and a little to one side of the Culebra cut. The Panama railroad crossed over the river, at the point chosen, on a plate girder bridge. The dry weather flow of the stream would not be sufficient for the proposed supply, and a storage reservoir was necessary.

The Rio Grande had many advantages as a source of supply. The elevation was sufficient to give a good head in the city. The railroad could be used to transport all material, and the pipe from the reservoir to the city could be laid along the track for nearly the entire distance. Branches could be led into the Culebra cut to supply steam shovels and locomotives, and the various canal camps of Paraiso, Pedro Miguel, Miraflores, Corozal, and La Boca, lying along the route, could also be furnished with water.

At the point selected, the Rio Grande comes down through a narrow gorge of trap rock. A small dam already existed here, having been built in 1889 by Buneau-Varilla, of the old French Canal Company, to supply water for dredging operations in Culebra cut. Buneau-Varilla's proposition to excavate the entire canal by dredging is well known, from his recent advocacy of this scheme before the Board of Consulting Engineers. He has adhered tenaciously to his plan, though the collapse of the old canal company, soon after he had his dredging plant installed, prevented any practical test of the idea in the Culebra cut.

The Buneau-Varilla dam created a reservoir of about 100 000-000 gallons. The drainage area tributary had never been sur-

veyed, but it was estimated at from 4 to 6 square miles. Partial run-off records had been kept by the French for a number of years, and they indicated ample flow to furnish 2 000 000 gallons per day with storage of about 400 000 000 gallons.

The dam itself was of the stone arch type, and an excellent piece of construction. Its crest was at elevation 217 feet above mean sea level. The rails of the Panama railroad, which limited the height to which the dam could be easily raised, were at elevation 242. A hasty survey of the basin showed that at elevation 237 the required net capacity of 400 000 000 gallons would be secured.

The complete system proposed for Panama included the construction of this enlarged storage reservoir at Rio Grande; a 16-inch cast-iron supply pipe line, 10 miles long, from Rio Grande to a 1 000 000 gallon distribution reservoir at Ancon Hill; and a distribution pipe system throughout the city, the latter requiring about 10 miles of cast-iron pipe in sizes from 20 inches down to 6 inches. The total estimated cost was $440 000 gold, and the work has been done inside of this figure.

There was some question as to what effect storage would have on water in the tropics. The small reservoir, already existing, had flooded its area without any cleaning or stripping, but in the fifteen or sixteen years that had elapsed, the influence of the rank tropical growth that was submerged seemed to have been entirely eliminated. Directly back of the dam was a mass of logs, branches, and vegetable matter, material brought down and accumulated there by the frequent floods. Decomposition was going on at this point, and water discharged at the lowest outlet in the dam smelled of hydrogen sulphide. The remainder of the reservoir was entirely free from anything objectionable; the water was clear and almost colorless and tasteless. Grass was growing in some places where the water was only five or six feet deep, but no objectionable growths appeared.

Samples of the water were examined with such limited appliances as were on the isthmus at that time, and nothing deleterious discovered. Perhaps the most satisfactory information was the fact that the water was used regularly by some of the laborers in Culebra cut, and found both agreeable and wholesome.

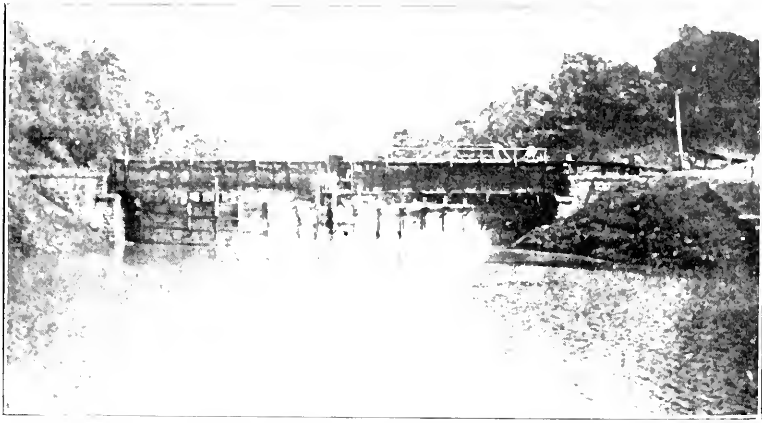

Fig. 1. Rio Grande Dam during Construction.

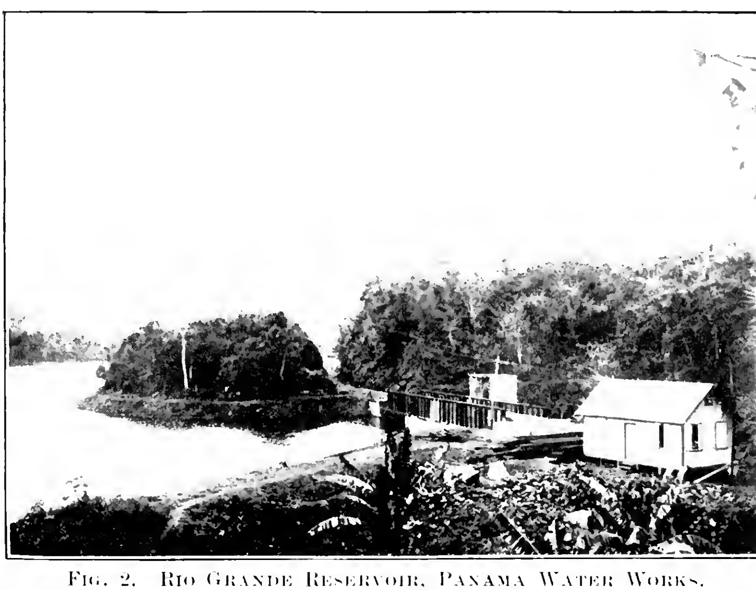

Fig. 2. Rio Grande Reservoir, Panama Water Works.

The sides of the proposed new basin were steep, giving very little area with less than 20 feet depth of water. The average depth of water would be about 40 feet. The watershed was practically uninhabited, and was controlled by the Commission.

Investigations for the water works were begun July 21, 1904, and the system as outlined was authorized by the Canal Commission on August 9. Work on the reservoir was begun immediately thereafter, all work being executed by forces in the employ of the Commission.

There were at this time about six hundred laborers, largely Jamaica negroes, working in the Culebra cut, a continuation of the old French organization. There were in addition perhaps five hundred or six hundred more laborers scattered over the isthmus, who were available for work. Some of these were new arrivals; a good many had been there since active French operations.

Negroes are susceptible to malaria. At least 75 per cent. of those who had been for any length of time on the isthmus were full of it. And malaria is just as potent in taking the energy from a negro as from a white man, which accounts in part for the often spoken of inefficiency of the Jamaican.

At the time the water works were being started, the Department of Health was being organized to get the hospitals into shape, to cut down vegetation, to ditch and drain, and to fumigate; the Building Department was getting ready to repair old houses and to build new ones; the Material and Supplies Department was sorting out old French stock, cleaning up storehouses, and preparing to store and deliver supplies; the Mechanical Department was putting the French shops in order and repairing some of the machinery; and at Colon docks were being built and yards and terminals cleared up ready to receive material.

To constitute the forces of the various departments there were only these 1 000 or 1 200 Jamaicans. Each department needed more men; and yet more men were not wanted on the isthmus until there were places to house them, food and water for them, and a chance to care for them, if they should be sick. Each department depended upon and needed the others, and yet in a sense they were rivals. It would have required transcendent genius to have distributed men and supplies equitably according to the various necessities.

As it was with the men, so it was with the material. Too much, coming in before the facilities for handling it were ready, would simply produce congestion, and Yankee ingenuity had a good opportunity to devise ways of getting work done with old French stock.

The order for the cast-iron pipe and valves for the Panama water works was placed in the United States. The first shipment reached the isthmus in January, 1905, the last shipment in May following.

In addition to the lack of men, good foremen were scarce. This perhaps was hardly more than was to be expected at that time, considering the reputation the place carried. In time, however, many good foremen did reach the isthmus.

Work on the Rio Grande reservoir was started under the direction of two of the engineering force, who were at first the only white men on the ground. Black foremen were all that could be secured.

The existing Buneau-Varilla reservoir was drawn down and thoroughly cleaned out. The additional area to be flowed by the enlarged basin, about sixty acres, was cleared and grubbed. All stumps and large roots were taken out, but no stripping of earth was done. Hardwood trees and logs were burned to charcoal for use later. The soil was a hard clay, apparently containing very little organic matter.

The dam as left by the French had its crest at elevation 217, was 40 feet high, 12 feet wide on the bottom, 4 feet wide on top, and was curved to a radius of about 180 feet. This dam was raised a little over 20 feet by extending vertically the top width of 4 feet. A substantial screen chamber in the center of the down stream side served to buttress this enlarged dam, and two smaller buttresses were built on either side of the center.

This extension work was of concrete mixed about 1:3:6, of Portland cement, seashell sand, and crushed trap rock. Old rails were bedded in the concrete. There were very few weeps through this work when the reservoir was filled.

The route of the supply line from Rio Grande to the city followed the gorge of the river for about 3 500 feet on a level grade, before meeting the railroad; the latter, meanwhile, having had a down grade from the dam of about 70 feet to the mile.

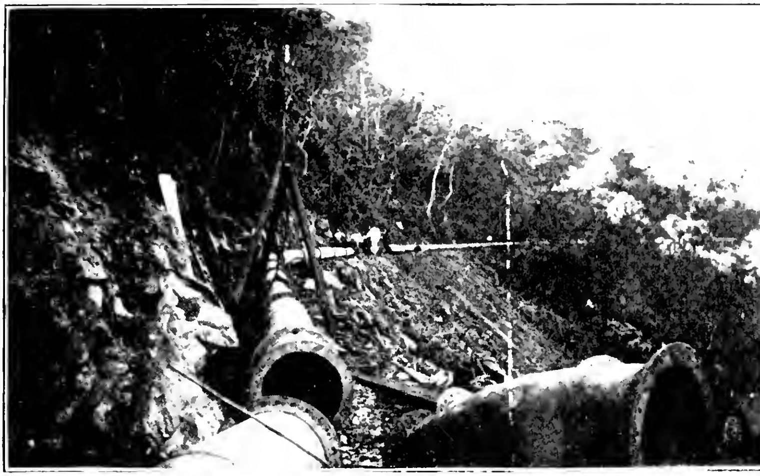

Fig. 1. Relaying Old 16-inch Galvanized Pipe for Panama Water Works.

Fig. 2. Laying Supply Pipe Line, Panama Water Works.

Along the bottom of this gorge Buneau-Varilla had laid a 20-inch galvanized iron pipe to convey water from his dam to the Culebra cut. This line had been left unused since 1889, and was overgrown and hidden by tropical vegetation. The pipes were in 16-foot lengths, of ¼-inch plates, single riveted, with flange joints. Barring some dents, which had not injured the galvanizing, the pipes were in first-class condition and practically as good as new. All French material was always of good quality and workmanship.

It would be necessary to protect with concrete any pipe laid in this gorge, as the latter will probably be filled with excavation from the Culebra cut. Under the conditions this galvanized pipe was considered suitable, and it was taken up and relaid as a part of the permanent line. Rubber gaskets were used for the joints. Enough bends were found to get around all curves, with some little aid at certain of the joints where the gaskets were beveled.

This galvanized pipe line was surrounded by 6 inches of Portland cement concrete, mixed about 1:3:5. In actual use under ful head, it has proved very satisfactory. Two small leaks appeared when water was first turned on, but these have since taken up.

From the end of this galvanized pipe to Ancon the supply line was laid alongside the track of the Panama railroad. The pipe was given a cover of about a foot.

Jamaica negroes were used entirely for laborers, pipe layers, and calkers. Some few of them had done similar work in Jamaica, but the majority had to be taught the entire business. The work, however, was very satisfactory. On the ten miles only three cracked pipes developed after the pressure was turned on, and very few joints had to be recalked.

Along the railroad, transportation was, of course, simple. The pipes were unloaded from the cars at night, when no trains were run.

In the city, the ordinary draught animal was a degenerate descendant of the Spanish horse, weighing about 700 pounds. The load these horses may carry is limited by city ordinance; not as a matter of humanity, however, but for purposes of municipal revenue. In hauling sand, the limit is about one third of a cubic yard.

The Department of Material and Supplies imported a number of mules from Chili and New Orleans. They did not stand the climate as well as the local horses, but were usually available for moving the heavier material, and served well for breaking the monopoly of the native teamsters.

The sewer and water pipes throughout the city were laid in the same trench, the latter on a shelf to one side of and above the sewers. The water pipes were given a cover of about 18 inches.

In general, the excavation was good and the trenches stood up well. Clay was the principal material encountered. Some soft rock and indurated clay was encountered that required blasting. The chief difficulty was the old underground drains. The streets were narrow and these drains could not be avoided. Moreover, nobody knew where they were.

Some interesting historical structures were uncovered. An underground passage, supposed to lead from the crypt of the cathedral to the water front, was encountered.

Many predictions were made as to the sickness that would break out in the city where the streets were dug up and the accumulations of centuries exposed. No unusual precautions were taken, except to sprinkle a liberal amount of chloride of lime when a particularly offensive drain was uncovered, and no bad results ensued as a consequence of the work.

The distribution reservoir, mentioned above as a part of the Panama system, is on a peculiar little peak of clay at Ancon, on which there is not much more than room enough for the basin. The walls are of concrete backed up with earth. Water surface is at elevation 137.

The location of this reservoir made it a rather difficult place to reach with material. A 20-inch gage railroad, with Decauville cars and locomotive, taken from old French stock, was laid from the Panama railroad to the foot of the hill; and a hoister, also from old French stock, operated cars on a similar track laid up the side of the hill.

This Ancon reservoir was not essential to the opening of the works, as the pipe was by-passed around it. Its construction was delayed in favor of more important matters until the dry season of 1905 came on; and during that season every drop of water

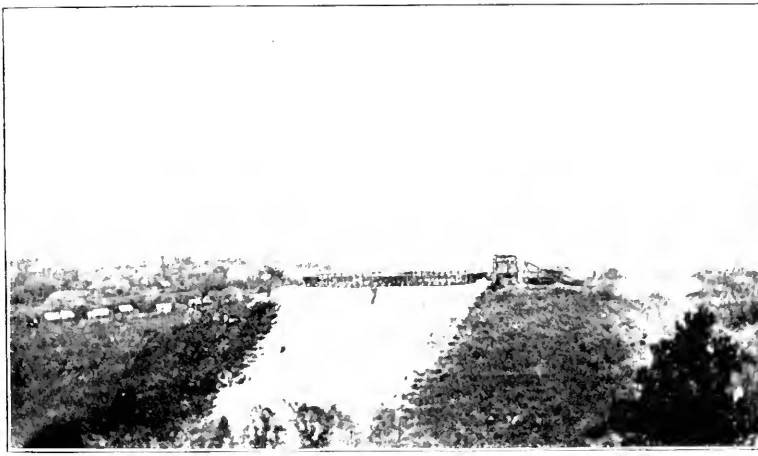

Fig. 1. Ancon Reservoir during Construction.

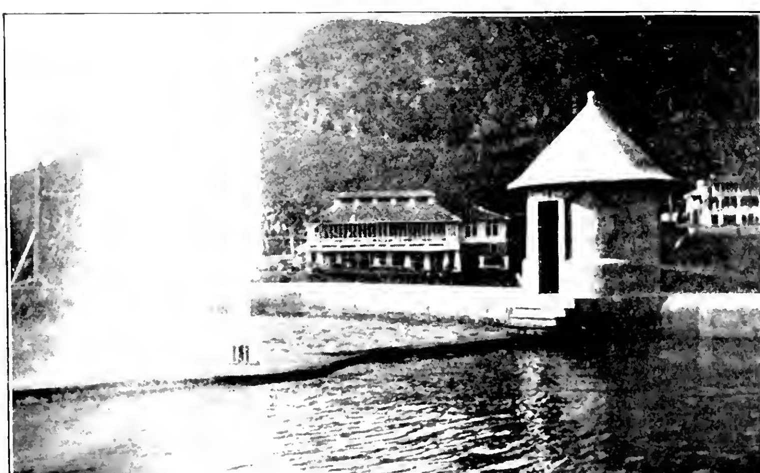

Fig. 2. Ancon Reservoir.

in the vicinity was needed for Ancon Hospital, and none was available for concrete.

The formal opening of the works took place July 4, 1905. The fire department of Panama celebrated the occasion, covering themselves with glory and the spectators with water.

At the time of this opening, between three and four miles of distribution pipe had been completed. Connection with the water works and sewers is made obligatory throughout the city, but a reasonable time is allowed for installation of plumbing work. Meanwhile, arrangements have been made at the fire hydrants in the streets so that people can get water for domestic use.

As soon as a district in Panama was supplied in this manner, all rain water receptacles were rigidly prohibited, and wells and cisterns were filled up. The worst yellow fever districts of the city were taken first in the order of pipe laying. The advance of this work has produced a marked decrease in the number of mosquitoes, and has been concurrent with the practical elimination of yellow fever.

For some months after the water from Rio Grande was introduced, examinations showed bacillus coli. For the past eight or nine months, since the withdrawal of the men working about the reservoir, these have not appeared, and very few of any other kind. The supply has been very satisfactory.

In addition to supplying the city of Panama, the Rio Grande system furnishes water to La Boca, Ancon, Corozal, Miraflores, Pedro Miguel, Paraiso, and part of Culebra, all canal towns. As Panama must pay for the system, it is necessary to measure the water; and for this purpose Venturi meters for the main line and branches have been provided.

For the Colon water works, more time was available for preliminary investigations than at Panama. A gravity supply was not practicable. After numerous possible sources were investigated a choice was made of Brazos Brook, lying back of Monkey Hill.

An excellent reservoir site was found on this brook at a point about three miles from Colon. Tributary to the reservoir is a drainage area of one square mile, without habitation. The reservoir has an area of 120 acres, a capacity of 520 000 000 gallons.

and an average depth of 20 feet. The sides are steep, and there will be little shallow flowage. Two earth dams, containing about 100 000 cubic yards, are required in the construction of the reservoir.

It is estimated that the watershed will yield easily 1 000 000 gallons per day. Should Colon outgrow this supply, an adjacent watershed of about equal area can be developed. The system has been designed with this in view.

Good data were available for estimating the capacity of this watershed. Reliable rainfall records have been kept at Colon for thirty years. The minimum rainfall is 86 inches; the average, 125 inches; the maximum, 160 inches.

There was also the small reservoir of the Panama railroad, already mentioned, which was built about 1870. This has a total drainage area of 24 acres, an area of 8 acres, a capacity of 20 000-000 gallons, and yields consistently 60 000 gallons per day, or at the rate of over 1 600 000 gallons per day per square mile. This Panama railroad reservoir had considerable shallow flowage and there was a population of about fifty on its watershed. But there was nothing disagreeable to the eye and taste about the water, though, of course, it was not fit for domestic use.

The complete Colon system provides for the storage reservoir on Brazos Brook, with a water surface at elevation 45 above sea level; a 20-inch cast-iron supply pipe from this reservoir to a pumping station near the Panama railroad at Monkey Hill; a 20-inch cast-iron force main from the pumping station to a standpipe; and a distribution pipe system in sizes down to 6 inches.

Like the Rio Grande reservoir, the Colon reservoir has been cleared and grubbed, but likewise no soil has been removed.

The system has not yet been completed.

While the water-works of Colon and Panama were being investigated and built, the canal force all along the line was being increased. One after another the old French camps were occupied, and new large hotels were erected at important points. Water was called for in each camp and the American canal worker demanded more water than did the French.

Temporary arrangements were made by patching up the old French plants and running them until new outfits could be pro-

cured, or until the plans of the canal had been sufficiently determined to permit of the camps being permanently located. Most of the machinery had been standing for years. In some cases water had been left in the cylinders, and the boilers had not been cleared out. Pumping stations, like everything else, were hidden away under a dense tropical growth. But nevertheless, almost everything worked, and nothing serious in the way of accidents occurred.

As plans developed, permanent water supplies were authorized. These have all been designed with a view to furnishing fire protection, for the average canal building, especially in the dry season, is a very bad fire risk.

By the middle of 1905 water systems were under construction at Emperador, where a gravity supply from a storage reservoir on the Comacho River will furnish 800 000 to 1 000 000 gallons per day to Empire, Culebra, and Culebra cut; at Gorgona, where a pumping plant is taking water from the Carabili River for Gorgona and the Bas Matachin shops; and at Bas Obispo, where another pumping plant is furnishing water from the Mandigo River for the camps in that vicinity.

All the territory about these streams, above points of intake, is practically uninhabited. A considerable force of men, however, has been working about them during construction. Examination of water shows some coli, as at Rio Grande, though it is expected that they will clear themselves as did that supply after the laborers were withdrawn.

It is generally known that during the past year there has been practically no yellow fever on the isthmus. The average force employed during this time has been 22 000. In the entire force there have been in this period 40 deaths from dysentery and 22 deaths from typhoid.

The maximum force employed by the French was 17 000 men in 1887, and about the same number in 1884. In the former year they had 85 deaths from dysentery in Ancon Hospital alone, the only place where statistics were kept. In 1884 they had 70 deaths from typhoid in Ancon alone.

The canal force is hard to control, and even with pure water supplies throughout the isthmus, there will probably be cases of typhoid in the future.

THE CLEVELAND TYPHOID FEVER EPIDEMIC OF 1903–1904.

BY GEORGE C. WHIPPLE, CONSULTING ENGINEER, NEW YORK, N. Y.

[*Read September 14, 1906.*]

There is one problem in the sanitary conservation of water supplies which the members of the New England Water Works Association have been but rarely called upon to solve. It is that of a city using a lake as a source of water supply, and at the same time using it as a place for the disposal of the city's sewage. To pump water from a lake into the water pipes of a city, to let it pass through houses and factories, through bath tubs and water-closets, through drains and through sewers back into the lake, and then to cause it to deposit its noxious accumulations at some place in the lake so that they shall not by any chance or mischance reach some other place from which the water supply is pumped — in short, to so operate the water supply and sewerage systems as to avoid a closed circuit — is a difficult problem from which you are fortunate to be spared.

We are not altogether spared from it. The JOURNAL of our association, Vol. X, 1896, p. 150, contains a description of the water supply of Burlington, Vt., where the danger of the closed circuit was convincingly demonstrated by our worthy President, Prof. William T. Sedgwick. Acting on his advice, the two poles of the sanitary system, the water supply intake and the sewage outfall, were put so far apart that "sparking" was for a time impossible. But gradual growth of the city so increased the lake pollution that for several years past the sparks of typhoid fever have been crossing the gap and flying into the city. That these sparks have not given rise to a conflagration has been due more to good luck than to adequate insulation.

What has happened in Burlington has happened in almost every city which takes its water supply unfiltered from an adjacent lake. Witness Chicago, Cleveland, Buffalo, Toledo, Lorain and many other places that might be named. I have mentioned Burlington first, not because she has been more careless with her water supply

than all the rest, but because she is one of our home New England cities well known to this association, and because the question of purification is now being considered by her city government. If the lake-water is to be continued in use, something must be done to break the unfortunate closed circuit. The most rational, effective, and economical method now known for doing this is by the installation of a water filtration plant. It is to be hoped that steps looking toward the betterment of the supply will be taken at an early date, and before a typhoid epidemic occurs, like that which recently overtook the city of Cleveland while the improvements in her water supply were in progress. This severe epidemic, one of the most important in recent years, has never been described in the technical journals; and it has been thought that an account of it might be appropriately added to the Transactions of this association, already so replete with the lore of epidemiology and public sanitation.

As the Cleveland epidemic was caused by a wholesale and long continued infection of the public water supply by the sewage of the city, a description of the water works and sewerage system should naturally precede an account of the typhoid fever situation.

THE BAY OF CLEVELAND AND THE WATER SUPPLY OF THE CITY.

The city of Cleveland is situated on an indentation in the southern coast line of Lake Erie, about one third of the way from Toledo to Buffalo. The indentation, or bay, is about forty miles long, measuring from Avon Point to Fairport, and about seven miles wide. The city is situated at the deepest point of the indentation. The water within the bay is nowhere deeper than sixty feet and its average depth may be taken roughly as fifty feet. The bottom is chiefly fine sand and clay, but in some places there are deposits of mud and in a few spots the bottom is rocky.

The Harbor. The Cuyahoga River flows into the lake through the heart of Cleveland, dividing the city into the East Side and the West Side. (See Map, Fig. 1.) At the mouth of the river the Government has constructed piers into the lake on either side about one quarter of a mile long. These help to provide a suitable channel of entry. In front of the river mouth and about one quarter of a mile from the end of these piers there is a breakwater parallel to

the shore line, which incloses the harbor. The breakwater has an opening opposite the river. The breakwater west of the opening has a wing which extends obliquely across to the shore so as to almost

FIG. 1. MAP OF CITY AND HARBOR OF CLEVELAND, SHOWING LOCATION OF WATER-WORKS INTAKES, AND THE OFFICIAL DUMPING GROUND.

completely inclose the harbor on that side. There is a small opening in this westerly wing which allows boats to enter and provides circulation of the water in the harbor. The harbor is now open on the east side, but an extension of the east breakwater is being made. Inside this harbor and in the river, dredging is going on almost continuously during the open season, and the material which is dredged is carried out to the open lake and dumped into the water.

The Water Supply of Cleveland. The water supply of the city is derived entirely from the lake. The old intake of the water works, often referred to as the "West Crib," or Crib No. 4, is located about $1\frac{1}{4}$ miles from the shore and 1 mile west of the mouth of the river. (See Fig. 1.) The crib is a wooden structure which protects the intake and serves also as a lighthouse. Water is taken from a depth of 12 to 28 feet below the surface, and only 12 feet from the bottom. From the West Crib two tunnels extend to the Division Street pumping station on the west side of the city, one 5 feet and the other 7 feet in diameter. The former was built in 1874 and the latter in 1891. The normal capacity of the tunnels is said to be 120 000 000 gallons per day. The pumping capacity at the Division Street station is 50 000 000 gallons per day. For about twenty years, or until the spring of 1904, this system furnished the water supply of the city.

In order to supply a greater quantity of water and at the same time to secure water of a better quality, new works were begun in 1890 and completed in 1904. The intake consists of a steel crib located about four miles from the shore and almost opposite the mouth of the Cuyahoga River. This crib is known as the "East Crib," or Crib No. 3. Water is taken at a depth of 10 to 28 feet below the surface, and 22 feet from the bottom. The crib is also used as a lighthouse. From it a 9-foot tunnel extends in a straight line to a pumping station located on the shore of the lake, at Kirtland Street. This tunnel has a length of 26 000 feet. Two temporary cribs, known as Crib No. 1 and Crib No. 2, which were used during the construction of the tunnel, are still standing. They are located at distances of 11 600 and 18 800 feet, respectively, from the pumping station. The nominal capacity of the tunnel is said to be 175 000 000 gallons per day, based on a velocity of 4 feet per second. The present pumping capacity at the Kirtland Street pumping station is 90 000 000 gallons per day.

LOCAL SOURCES OF POLLUTION.

The chief local sources of pollution of the water of Lake Erie in the vicinity of Cleveland are:

1. The city sewers which discharge into the river and along the water front.

2. The Cuyahoga River.
3. The Rocky River.
4. The shore wash and the stirring up of the bottom of the lake by the winds.
5. The dumping of dredged material.
6. The accidental pollution from steamboats.

The Sewage of the City. All of the sewage of the city goes directly or indirectly into the lake. It has been estimated that the sewage of about 225 000 people runs into the Cuyahoga River and that the sewage of more than 200 000 people empties directly into the lake along the water front between Waverly Avenue and Gordon Park.

The Waverly Avenue sewer, which takes the sewage of about 22 600 people, discharges near the west entrance of the breakwater. The sewers at Seneca, Ontario, and Erie streets also discharge near the east side of the harbor. The intercepting system of sewers which is now being constructed is intended to remove practically all of the sewage from the river and the water front and carry it to a point about nine miles east of the harbor, discharging it at a considerable distance from the shore. It will be many years before this system of intercepting sewers can be completed, and it has been suggested to establish a temporary outfall at Marquette Street to be used until the entire system shall be completed. By using this it would be possible to obtain partial relief to the river in a shorter time than by waiting for the completion of the whole system. It seems probable that even after the construction of the intercepting system of sewers the Cuyahoga River will still be a nuisance and that it will probably be necessary to adopt some plan thereafter for the amelioration of its conditions.

Amount and Character of the Sewage. From what is known in general of the *per capita* constituents of sewage it has been calculated that during each day there is discharged into Lake Erie at Cleveland at least 100 tons of solid matter, of which about 70 tons are mineral, and 30 tons organic. Of the mineral matter about 12 tons represents common salt. About 3½ tons of organic nitrogen are also discharged daily and about 3 tons of nitrogen as free ammonia. It has been further estimated that the number of bacteria

in the city sewage amounts to more than one hundred million billion daily, of which it is fair to assume that nearly ten million billion are *B. coli* or allied species. These figures, of course, mean little except when taken in connection with dilution as described below. They serve merely to indicate the immense amount of polluting substances which enter the lake and which have to be taken into consideration in connection with the purity of the water supply.

Except in the case of the Cuyahoga River, the quantity of water discharged through the sewers is not sufficient to create currents setting into the lake which preserve their identity for any considerable distance from the shore, and the dispersion of the sewage by the action of wind and wave begins near the shore line. The dispersion of the sewage is materially influenced by its temperature as compared with that of the lake water. The presence or absence of an ice-sheet, the relative temperatures of the water and sewage, and the increased density of sewage due to its mineral constituents, are all matters which must enter into a complete discussion of the problem.

Cuyahoga River. The Cuyahoga River has a drainage area of about 805 square miles. In its upper reaches it receives more or less pollution. The rural population on the watershed is estimated as about 32 500, or about 40 per square mile; the village population (cities and towns of less than 4 000 population), 10 000, or 12 per square mile; the urban population (cities of over 4 000 inhabitants), 55 000, or 69 per square mile; making a total of 121 per square mile. The principal city on the upper part of the river is Akron, which in 1900 had a population of 42 728. If it be assumed that the sewage of 228 000 of the population of Cleveland drains into the river, the population per square mile on the entire watershed above its mouth becomes 404, of which 352 represent urban population.

The Cuyahoga River in the lower part of its course is tortuous and its flow is ordinarily sluggish. Its surface elevation changes according to the lake level, and the stream has been rightly termed a slack-water estuary. The amount of sewage discharged into the river is so great, its current is so slow, and its volume relatively so small that the water of the river is nearly always foul and ill-smelling. Besides sewage, the river receives the waters from several

small brooks, or runs, which are for the most part highly polluted. Immense quantities of manufacturing wastes are discharged into the river or into these runs. From the works of the Standard Oil Company very large quantities of crude oil and other waste products are discharged. This oily matter spreads out over the surface of the water, giving it an offensive appearance and a bad odor, and, what is more important, forms a film which prevents, to a great extent, the absorption of oxygen by the water. As a result of the great amount of pollution which the river water receives and of this lack of oxygen, the stream is nothing more nor less than an elongated septic tank. The suspended matter of the sewage and manufacturing wastes, together with the sediment brought down from the upper portions of the watershed, settles in the lower reaches of the river and forms a thick, black mud. This decomposes and in warm weather bubbles of gas may be seen rising through the water and breaking at the surface. When the river is in flood some of the mud is carried out into the lake, but it is only the severe freshets which scour the bottom of the river to an appreciable extent. In fact, deposits accumulate so constantly that it is necessary to dredge the channel continuously in order to maintain a depth of water sufficient for navigation. It has been roughly estimated that the amount of sediment carried into the lake each year by the Cuyahoga River is in the vicinity of 200 000 cubic yards. Most of this is transported during the spring freshets, when the discharge of the river occasionally amounts to 5 000 or 10 000 cu. ft. per sec. The flood of January 22, 1904, which produced a daily discharge of nearly 25 000 cu. ft. per sec., and which maintained a discharge of more than 10 000 cu. ft. per sec. for several days, caused such a scouring of the river bed that more than 200 000 cubic yards of mud were carried into the lake in one week.

The mud in the river and harbor of Cleveland is polluted. Ordinarily it contains from 1 000 000 to 5 000 000 bacteria per gram and shows the presence of *B. coli* in large numbers. It also contains in large numbers another organism similar in some respects to *B. coli*, and one which has been found to be quite widely distributed through the water of the lake in the vicinity of Cleveland. The samples of mud invariably have an oily odor.

The pollution which the lake receives from the Cuyahoga River has a more important bearing on the quality of the water supply of the city than the sewage discharged along the lake front, because of the greater volume of the river. There is good reason to believe that at times the river flows as a well-defined current out into the lake for a considerable distance from the shore, its waters gradually dispersing and becoming mixed with the water of the lake. The result is that when the conditions are such that this current is directed straight towards the intakes the dilution of the sewage is less, and the pollution of the water supply greater, than it would be if the sewage were discharged uniformly along the entire lake front.

Rocky River. The Rocky River discharges into Lake Erie at a point about six miles west of the city. It has a drainage area of 347 square miles, on which dwells a population of about 15 000 people or 72 per square mile. The river receives only a small amount of direct sewage pollution.

Mud Deposits and the Shore Wash. Through the constant discharge of sewage, manufacturing wastes, and other polluting substances into the lake for many years, the shores of the lake in front of Cleveland are unclean and the deposits along the shores are foul. When these deposits are stirred up through the action of the wind and waves, the suspended matter is carried out into the bay, only to be deposited again when the water becomes quiet. Thus for many years the mud at the bottom of the lake has been gradually becoming polluted for greater and greater distances from the shore.

The streams along the shore have been discharging great quantities of silt and clay into the lake for many years, and while in many places near Cleveland the bottom of the lake is sandy or rocky, there are, according to the government charts, large areas covered with clay or mud. At certain seasons of the year, especially during the spring and fall, when the temperature differentials between the surface and bottom are small, the action of the wind stirs up this clay and mud, and materially increases the turbidity of the water in this portion of the lake.

The Dumping of Dredged Material. The material dredged from the river and harbor has, until recently, been dumped into the

lake between the first and second temporary cribs, on the line of the new tunnel. The boundaries of this dumping ground were officially established by the United States Government a number of years ago. The dumping ground was a rectangle formed by north, south, east, and west lines drawn through Crib No. 1 and Crib No. 2. All material dredged from the harbor was required to be dumped within this area, and a float to mark the spot was established by the United States engineers, about ten thousand feet southeast of the new intake. The amount of mud and clay dredged every year from the Cuyahoga River and the harbor of Cleveland is said to be about two hundred thousand cubic yards, which is approximately the annual amount of material carried in suspension by the river during the year.

The night soil of the city is taken in scows and is carried out into the lake eight or ten miles from the intake and dumped. The scows in their ordinary course pass within about half a mile of the new intake.

The effect of the dumping of polluted material from the river and harbor upon the quality of the water in the city was occasionally evident in the analyses. On June 4 an inspection of the dumping ground was made and the operation of dumping witnessed. It was found that the surface of the water in the vicinity of the float was covered with a thin film of oil which spread out over a wide area. This oil came from the mud. A sample of water was collected near the float immediately after the scow had dumped, and a series of samples was taken at intervals of about one quarter of a mile along the line in the direction in which the wind happened to be blowing, namely, towards the east. The water had an oily odor for more than a mile from the dumping ground. The number of bacteria decreased from the dumping ground towards the eastward, but the colon bacillus could be detected in all of the samples. Had the wind been blowing towards the intake, *i. e.*, from the southeast instead of from the west, the oily water would have been driven nearly to the intake of the water supply. Samples of mud from the river and from the bottom of the lake taken on the same day showed marked variations in their bacterial contents. The mud dredged from the Cuyahoga River contained 26 000 000 bacteria per gram of dry material, while the mud from

the bottom of the dumping ground contained 31 000 000. A second sample of mud a short distance from the float contained about 20 000 000. A sample from the bottom of the lake at the east end of the dumping ground contained only 125 000, while a sample of sand from the bottom between Cribs No. 2 and No. 3 contained only 154 per gram. Moreover, the last two samples gave negative tests for *B. coli*, while the others gave positive tests. Prior to June 4 samples of water collected at the Kirtland Street pumping station had, in a few instances, distinct oily odors, and it had been observed that when such odors were present the samples sometimes contained the colon bacillus in small numbers. On investigation it was found that these conditions existed when the wind had been blowing briskly from the southeast, and it seemed obvious that the water at such times was influenced by the material deposited at the authorized dumping ground.

On September 3 other samples were collected at the dumping ground immediately after dumping and several hours after that. Samples collected immediately after the scow had dumped showed a high turbidity and large numbers of bacteria near the surface, and also at the bottom, with fewer bacteria at the mid-depth. Three hours later the conditions at the surface had improved but the number of bacteria at the bottom remained high. The test for the colon bacillus corresponded with these results of turbidity.

There has been no evidence as yet to show that the dumping of dredged material has caused an actual infection of the water supply, but evidently the deposition of polluted mud at the point mentioned was a menace to the sanitary quality of the water supply and hence to the health of the community. The matter was reported to the War Department through the United States Engineers, and as a result a new dumping ground was authorized. This was located about two miles from the shore, opposite Dean Street. It consisted of a rectangle 2 miles long and 1 mile wide, parallel with the shore.

Accidental Pollution from Boats. The steamers plying between Cleveland and various other cities on the lake pass within a mile or so of the water-works intake, and some of the fishing boats and scows often pass much nearer. It is probable that the effect

of accidental pollution from these boats would be extremely small, yet it is within the bounds of possibility. This accidental pollution is, of course, beyond the control of the city.

Pollution at the Crib. The crib is used as a lighthouse, and this necessitates the constant presence of a keeper. At times, also, when repairs are being made, several men may be employed at the crib for a number of days. The disposal of fecal matter at the crib, therefore, becomes a matter of importance. To allow it to accumulate at the crib would create a nuisance, while to throw it from the crib into the lake would endanger the water supply. The present method consists in carrying the material in a row boat and dumping it into the lake at a considerable distance from the crib. This cannot be done in winter and it is evident that a well-regulated system of disposal, with efficient disinfection, should be maintained.

Pollution by Leakage into the Tunnel. In some cases where a water supply has been drawn from a lake the water has become polluted by leakage into the tunnel or pipe-line. This matter has been given careful consideration, but from the data collected there is no reason to believe that such pollution of the water supply of Cleveland does or can take place.

TYPHOID FEVER IN CLEVELAND.

Past History. For many years the typhoid fever death-rate of Cleveland has been higher than it should be, and there is good reason to believe that this has been due largely to the character of the public water supply. Statistics furnished by the Department of Public Health show that the average typhoid death-rate for the 32 years from 1873 to 1904, inclusive, was 52 per 100 000, while it has varied in different years from 21 to 114. The following figures show the number of years when the typhoid fever death-rate has been between certain figures:

Typhoid Fever Death-Rate per 100 000.	Number of Years when this Death-Rate existed.
Below 20	0
Between 20 and 30	2
Between 30 and 40	8
Between 40 and 50	5
Between 50 and 60	8
Between 60 and 70	6
Between 70 and 80	1
Between 80 and 90	0
Between 90 and 100	1
Above 100	1

Since 1880 there has been a general lowering of the rate, due probably to better general sanitation, to the abandonment of local wells, etc. Thus, during the ten years preceding the epidemic of 1903 the average death-rate from typhoid fever was 37 per 100 000, which is much lower than the average for the entire period. This figure is only slightly above the average for the cities of the United States which have more than 30 000 inhabitants.

The records of the United States Bureau of Labor show that for the six years from 1896 to 1901, inclusive, the average annual typhoid fever death-rate for the 19 000 000 people included in these cities has varied from 33 to 38 and has averaged about 35 per 100 000. The following are the average figures for the six years mentioned for these cities which had more than 100 000 inhabitants in 1900:

Average Typhoid Fever Death-Rate for Six Years for Those Cities Which had More than 100 000 Inhabitants in 1900.

Name of City.	Rate.
Pittsburgh	120.2
Alleghany	96.6
Washington	65.7
Louisville	58.6
Philadelphia	52.0
Cleveland	50.1
New Orleans	48.3
Denver	45.8
Cincinnati	44.7
Minneapolis	43.0
New Haven	42.6
Kansas City	42.2
Los Angeles	41.2

Name of City.	Rate.
Indianapolis	38.8
Memphis	36.2
Baltimore	34.8
Columbus	33.5
St. Louis	32.4
Chicago	31.5
Toledo	31.2
Paterson	30.7
San Francisco	30.6
Buffalo	28.5
Boston	25.8
Scranton	23.4
Providence	22.9
Omaha	22.5
Newark	21.7
Syracuse	21.6
Jersey City	20.4
New York	19.6
Detroit	18.9
St. Paul	17.7
Milwaukee	17.6
Worcester	17.3
Fall River	16.0
St. Joseph	15.6
Rochester	15.5

It will be seen that of the 38 cities which had more than 100 000 inhabitants at the time of the last census, 32 had lower typhoid rates than Cleveland and only 5 had higher rates.

As a general rule a continued typhoid death-rate above 20 is an indication that something is at fault with the public water supply, and the rate for Cleveland was above this for more than thirty years. During 1903 the city was visited by a severe epidemic of typhoid fever which continued for many months and gave a yearly death-rate of 114 per 100 000, and again during the spring of 1904 another epidemic occurred which caused a death-rate for the year of 48 per 100 000. Had this epidemic not been checked by the use of water from the new intake, it would probably have exceeded in intensity the epidemic of any preceding year. Details of these epidemics are given below.

The statistics do not point to a well-marked seasonal distribution of typhoid fever in Cleveland, although ordinarily the

disease has been most prevalent during the autumn, as is the case in most cities. During several years the maximum number of cases occurred in the spring, while the epidemics of 1903 and 1904 both started in the winter. This abnormal seasonal distribution, taken in connection with the general high typhoid fever death-rate of the city and the general distribution of the cases throughout the city, are all facts which point to the public water supply as being the cause of most of the typhoid.

Comparison of the annual typhoid fever death-rates of Cleveland with those of other cities on Lake Erie fails to show any relation between them, and, as will be pointed out later, there is no reason to believe that any of the cities on the watershed of Lake Erie are in any way responsible for the typhoid fever in Cleveland, unless we except those which drain directly into the Cuyahoga River, and even in the case of Akron, the largest city on the Cuyahoga River watershed, no direct correspondence can be discerned from the statistics. The evidence seems conclusive that the greater part of the typhoid fever in Cleveland in the past has been due to infected sewage of the city which has reached the public water supply, and there is further reason to believe that that part of the sewage which enters the Cuyahoga River has been chiefly responsible for it.

Typhoid Fever in 1902. During the year 1902 there was less typhoid fever in Cleveland than usual, the death-rate being only 33 per 100 000 inhabitants, yet even during this year it is possible to detect some relation between the prevalence of typhoid fever and the probable pollution of the water supply. (See diagram, Fig. 2.)

The old intake was so situated that when the wind was blowing from the south or southeast the water of the Cuyahoga River and the sewage of the city would be carried toward it (see map, Fig. 1), and if the wind was strong enough, and the flow of the river sufficient, evidence of the pollution was often shown by the oily odor of the water. Further evidence is furnished by the typhoid fever statistics. In looking over the records for the year 1902 all of the fluctuations in the typhoid fever cases cannot be explained, but it is noticeable that whenever the Cuyahoga River was in flood, and when at the same time the wind was blowing strongly from the south or southeast, thus producing a

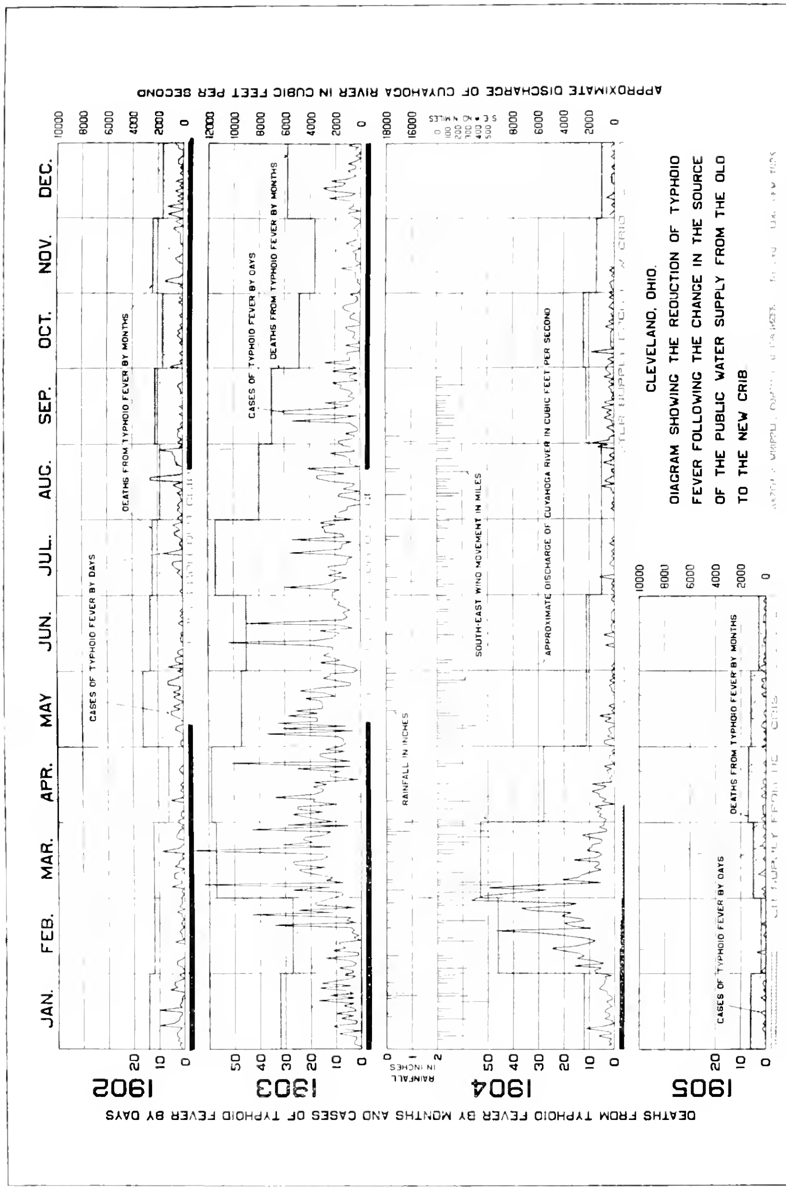
CLEVELAND, OHIO.
DIAGRAM SHOWING THE REDUCTION OF TYPHOID FEVER FOLLOWING THE CHANGE IN THE SOURCE OF THE PUBLIC WATER SUPPLY FROM THE OLD TO THE NEW CRIB
APPROXIMATE DISCHARGE OF CUYAHOGA RIVER IN CUBIC FEET PER SECOND
DEATHS FROM TYPHOID FEVER BY MONTHS AND CASES OF TYPHOID FEVER BY DAYS
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1902
1903
1904
1905
CASES OF TYPHOID FEVER BY DAYS
DEATHS FROM TYPHOID FEVER BY MONTHS
RAINFALL IN INCHES
SOUTH-EAST WIND MOVEMENT IN MILES
APPROXIMATE DISCHARGE OF CUYAHOGA RIVER IN CUBIC FEET PER SECOND

Fig. 2.

fall in the lake level, an increase of typhoid fever occurred within about ten days or two weeks thereafter. It is noticeable also that floods in the river which occurred when the winds were blowing towards the shore instead of away from it, thus producing a rise in the lake level, were not followed by typhoid fever, and southeasterly gales not accompanied by a moderate flood in the river did not cause a material increase in the number of cases. It appeared to be necessary to have the two conditions operating together in order to cause a pollution of the water at the old intake, sufficient to show a rise in the typhoid morbidity rate of the city. The fact should be noted, however, that a severe west wind sometimes causes the lake level to drop. The following may be taken as typical examples:

There are no data for the discharge of the Cuyahoga River prior to March 12, 1902, hence no comparisons can be made before that date. During the early part of the year 1902, there were 3 days when the number of reported cases of typhoid showed a decided increase, namely, on January 10, January 16, and January 24. It is worth notice that 8 days before January 10 there was a drop in the lake level due to a strong south and southeast wind; 11 days before the 16th, there was a similar lowering of the level from the same cause, and 9 days before the 24th there was also a lowering of the lake level. Yet on the 20th a severe southeast wind was not followed by typhoid fever, unless the slight increase on February 4, 15 days after, was due to it.

In making these and other similar comparisons it must be remembered that the dates when the cases were reported are not always the dates when the patients were taken sick (although the two dates ought not to differ widely, and seldom do except in the hospital cases).

On March 12, 1902, there was a severe southeasterly storm, the total wind movement for the day being 689 miles, and the velocity exceeding 30 miles an hour for nine hours. This was accompanied by a rainfall which produced a slight flood in the river. Eight days later there was a marked increase in the number of typhoid fever cases in the city, and the number would probably have been larger if the wind had not changed on the following day and blown strongly from the west. On May 5

there was a similar flood of the river, accompanied by a southeast wind, which was followed, after 8 days, by an increase of typhoid fever. On July 1, 2, and 3 the river was again in flood, with the wind blowing strongly from the southeast, and after 8 or 10 days there was an increase of typhoid fever. On September 28 there was a moderate flood of the river and a southeast wind which was followed by a slight increase of typhoid fever, and the same was true on August 20 and November 18. Between December 16 and December 23 the conditions of wind and stream flow were for several days so favorable to the pollution of the water supply that they may be said to have given rise to the epidemic which occurred in 1903, and which is described below. On the other hand a freshet, which occurred on April 9, 1902, raised the stream flow to 10 300 cubic feet per second, but at this time there was a strong northeast wind which apparently raised the lake level and protected the intake from pollution, as it was not followed by an increase of typhoid fever. This was also true of the floods which occurred on March 29, June 29, and July 29. On June 15, the river was in flood, but at this time, although the wind was blowing from the southeast, the velocity was very low and no typhoid fever resulted. An increase of typhoid fever on August 17 occurred 9 days after a slight flood in the river when the wind was blowing from the west.

Throughout the year there were many times when the wind blew strongly from the south or southeast, unaccompanied by a high river flow, but so far as can be learned from the statistics these occasions were not followed by typhoid.

It is not to be presumed that all typhoid fever in the city can be traced to the drinking water, because milk, various foods, flies, etc., may spread infection. Yet in spite of this the evidence seems sufficient to show that even in a year when typhoid fever was not more than usually prevalent the connection between pollution of the public water supply and the sudden outbreaks of diseases could be detected.

Typhoid Fever in 1903. The typhoid fever epidemic in 1903 may be said to have begun on January 6, when 9 new cases were reported. This was just 10 days after a heavy rainfall, which increased the discharge of the river and which was followed by

fresh southeasterly winds. For two or three weeks previous to this the river had maintained a discharge of more than 2 000 cu. ft. per sec. and the winds had been high, causing unusually great fluctuations of the lake level. On January 4 the stream discharge increased to 4 600 cu. ft. per sec., and between January 7 and January 15 the winds were again strong and the fluctuations of the lake level considerable. Thus, between January 8 and 9 the lake level dropped 0.6 foot and between January 11 and 12 0.9 foot. About ten or twelve days later new cases of typhoid fever became still more numerous, but after January 27 they became fewer. On January 27, 28, and 29, the flow of the Cuyahoga River increased to 8 400 cu. ft. per sec., and on the 30th, under the influence of a strong southwest wind, the total wind movement for the day being 923 miles, the lake level was lowered 0.5 foot, the whole mass of water in the lake being driven eastward. Ten days later the number of typhoid fever cases again increased

On February 2, 3, and 4 there was a second freshet. The discharge of the river reached 8 300 cu. ft. per sec., and another strong west wind drove the water eastward and lowered the level of the lake 1.1 feet. Fifteen days after that there were 34 new cases of typhoid fever reported in one day.

On February 8 there was another drop in the lake level which amounted to 1.7 feet, due to a westerly wind, and fifteen days after there were forty-three new cases reported in a single day. From this time on, through the spring and summer, large numbers of new cases were reported daily. As the sewage of the city became more and more infected with typhoid bacilli a smaller amount of pollution of the water supply would give rise to greater numbers of typhoid fever cases. Under the existing conditions the epidemic was in a sense self-sustaining, the typhoid germs making the circuit from one individual to another through sewer, lake, tunnel, and distribution pipes.

It is impossible to explain all of the fluctuations in the typhoid morbidity during this period, but the data at hand indicate that the wind exerted the controlling influence on the typhoid fever in the city. This is illustrated by the following instances: From February 18 to February 23 the prevailing wind was from the

south, and on the 23d the southerly wind movement was 331 miles. This fact would explain the general trend of the typhoid curve during the early part of March, with its climax of 62 cases on March 5, eleven days after the high wind. The flood of February 27 and 28, with its southeasterly wind movement of 616 miles, probably caused the increase in the number of cases between March 10 and March 14, but the effect of this storm does not seem to have produced as many cases as would be naturally expected. This may have been due to the fact that the severity of the storm raised the general lake level in the west portion of the lake, so that the effect of the discharge of the river was less than it would have been otherwise. The largest number of cases reported on any day of 1903, namely, 66, occurred on March 19, and was preceded 12 days before by a southeasterly wind movement of 398 miles, accompanied by a slight flood in the river. After this record-breaking day the morbidity fell to about twenty cases per day. An increase to forty-three cases on the 27th followed about 8 days after another heavy southeasterly wind. On March 30, the wind was in the southeast, and 11 days later there was another rise in the typhoid curve. During March the general lake level rose rapidly and the river discharge steadily decreased. This tended to reduce the danger from pollution, and the typhoid morbidity would probably have been less had not the wind at times continued to blow strongly from the southeast.

During the first three weeks of April there was a general downward trend of the typhoid curve; but the southeasterly storm of April 3, accompanied by a flood in the river, prevented the morbidity from falling as it probably otherwise would have done, while a second storm on the 11th caused the morbidity rate to rise again. Twelve days after this date 51 cases were reported in a single day. After this there was a drop in the morbidity due to a two-weeks period of calm weather.

Early in May the typhoid morbidity again increased and remained high, though gradually decreasing throughout the month, being kept up by constant south and southeast winds. By the first of June very few new cases were being reported, but they soon began to increase again, and on June 11, 52 new cases occurred in one day. This followed 12 or 14 days after

some rather violent fluctuations of the lake levels and 10 days after a heavy rain. On the 19th, 45 new cases were reported, 13 days after another southeasterly storm.

Throughout the summer of 1903 typhoid fever was constantly present in the city, and whenever the winds were favorable there was an increase in the morbidity rate. On July 30 there were 30 new cases, 11 days after high southerly winds. On July 17 there were 28 cases in one day, 12 days after a heavy rain. Continued southerly winds during the first half of July were followed by a high morbidity rate during the last half.

During the first two weeks of August there was a slight decrease in the morbidity, but from the 15th to the 20th there was an increase which followed about two weeks after a slight flood in the river. From then until the 9th of September the rate was fairly low. On August 27, however, there was a severe rain which caused the discharge of the Cuyahoga River to rise to 11 000 cu. ft. per sec. The lake level at this time fluctuated considerably and 12 days later the daily number of cases jumped first to 27 and then to 30 and 31.

From this time on throughout the year the numbers of the new cases were comparatively small, but there were few days when no new cases were reported. September was a month of high southeast winds. The total southeasterly wind movement was 2 309 miles. This fact probably explains the constant presence of typhoid fever at that time. During October the southeasterly wind movement was lower and the amount of typhoid fever in the city was also less. On September 17 and 18 there was a heavy rain accompanied by a drop in the lake level, due to a strong west wind which drove the lake water towards the easterly end of the lake. About two weeks after this there was another rise in the typhoid curve. On October 4 there was another rain with a southeast wind, and after 11 days this was followed by a slight increase of typhoid fever. On October 7 and 8 there was a severe southeasterly storm, which caused a slight flood in the river, but this apparently caused only a slight increase in the typhoid curve.

During November the typhoid morbidity rate was relatively low in spite of the fact that there were considerable fluctuations

in the lake level. Apparently the sewage of the city was becoming less infected than it had been. On November 11, however, the southeasterly wind movement was 462 miles, and 9 days later typhoid increased slightly. On November 16 and 17 there was another southerly storm which produced a slight flood in the river. This was the beginning of a new period of infection which extended over the two first weeks in December and reached climatical points on December 8 and December 12, both of which occurred about two weeks after sudden drops in the lake level. During the last two weeks of December typhoid fever was continually present in the city, but the amount was small.

During the year 1903 there were 3 443 cases of typhoid fever reported and 472 deaths. The ratio of reported cases to deaths was 7.3 to 1. Under ordinary conditions this ratio is as high as 10 or 12 to 1, and at times as high as 15 to 1. That is, ordinarily, there are 10 or 15 cases for every death. Many of the cases in the city were, of course, mild, and were never reported to the Health Department. Assuming the ratio of cases to deaths to be 12 to 1 we find there must have been in Cleveland during the year 1903 as many as 5 650 cases of typhoid fever.

Typhoid Fever in 1904. At the beginning of the year 1904 typhoid fever was prevalent in Cleveland, but the number of new cases reported daily was quite low, seldom exceeding five. On January 20, 21, and 22 there occurred a memorable flood. The rainfall for the three days was 2.57 inches, while the wind blew strongly from the southeast. Moreover, on the day preceding this storm the southeasterly wind movement was 515 miles. On the 21st the discharge of the Cuyahoga River rose to more than 23 000 cu. ft. per sec., and for more than a week it remained above 5 000 cu. ft. per sec. The flood was so great that it washed out of the river bed immense quantities of mud. From data in possession of the United States engineers it seems probable that at this time more than 200 000 cubic yards of mud were carried down the river into the lake. This is more than the entire amount ordinarily discharged in a whole year. On January 31, just 10 days after the flood, typhoid fever began to increase again and continued to increase until February 10, when 25 new cases were reported in one day. After that they decreased for several days.

On February 6 and 7 another southerly storm caused a second flood in the river. This was much less severe than the one previously mentioned, but the discharge of the stream rose to more than 11 000 cu. ft. per sec. and remained higher than 3 000 cu. ft. per sec. for about a week. The sewage of the city had by this time become thoroughly infected with the bacilli of typhoid fever, so that the effect of a flood on February 7 was to cause the number of cases to increase on February 17 to 47 per day. A week of calm weather followed this storm and the amount of typhoid fever in the city dropped off. On the 13th and 14th of February there occurred a very strong southeast wind, and 10 days later the morbidity rate rose again. A southeast wind on February 21 caused another increase, which carried the number of cases to 57 on February 29. They remained high for several days and then decreased, because of the timely introduction of water from the new crib, as described below.

During the last few days of February another very severe southeast storm occurred. The discharge of the river rose to 11 000 cu. ft. per sec., and remained above 5 000 cu. ft. per sec. for more than a week. During this time, moreover, the lake level fluctuated considerably. The conditions were all favorable for a continuance of the epidemic, and the sewage at that time was probably more strongly infected with the bacilli of typhoid fever than at any other time during the preceding year. Had it not been, therefore, for the introduction of water from the new crib there is every reason to believe that the epidemic would have assumed much more serious proportions than at any time during the previous year, and before the effect of this climax could have passed the conditions again became favorable for further infection of the supply. On March 25 and 26 there was another southeasterly storm which carried the discharge of the Cuyahoga River to 11 000 cu. ft. per sec., and on the 31st of March there was another storm which caused the river to again rise to 11 000 cu. ft. per sec. Each of these storms would unquestionably have given the typhoid fever epidemic a new stimulus and would have produced appalling results. The month of April was comparatively free of southeasterly winds, and the results of this would probably have been to check the intensity of the epidemic.

Before the epidemic, however, could have been checked by natural causes the new water supply was gradually introduced, and with the introduction of the purer water the long typhoid fever epidemic, which really may be considered to have covered about sixteen months, drew to a close.

During the sixteen months from January, 1903, until May, 1904, there were 4 578 cases of typhoid fever reported to the Health Department in Cleveland, and 611 deaths. If we assume the true ratio of cases to deaths as 12 to 1 we find that the actual number of cases in the city during that period was over 7 000. This was practically one case for every 60 inhabitants of the city. It would be a very conservative estimate to place the financial loss of the city due to this epidemic as upwards of $3 000 000.

The introduction of water from the new intake took place as follows: The pumps at the Kirtland Street station were started on February 10, 1904, and the pumps at the Division Street station were finally shut down on April 7. Between these two dates water was drawn from both intakes. Between February 10 and February 22 only a small amount of water was pumped at Kirtland Street, but between February 22 and March 1 about one half of the water was drawn from each crib. Between March 1 and March 15 three quarters to five sixths of the water was pumped from the new crib and between March 15 and March 31, about three quarters. Since April 7 all of the water has been drawn from the new steel crib except for a short time on July 21, when, owing to the necessity of temporarily shutting down some of the pumps at Kirtland Street, it was necessary to pump a small amount of water (about one fifth of the supply of the city) from the Division Street station.

A study of the Health Department statistics shows that the decrease in typhoid fever occurred in steps which corresponded with the progressive increase in the use of water from the new intake. It must be remembered that the period of incubation of typhoid fever is from ten days to two weeks or more, so that any change in the character of the public water supply would not make itself felt in the morbidity rate until after that interval of time. Bearing this in mind the following figures have been compiled from the records of the Board of Health to illustrate the

relation between the typhoid morbidity and the water supply of the city:

Period.	Average Number of New Cases of Typhoid Fever Reported Daily.
January 1 to January 31, 1904: Period prior to the epidemic caused by flood	2.84
February 1 to March 5: Period of epidemic corresponding to exclusive use of old supply	20.91
March 6 to March 15: Period of epidemic corresponding to use of one half of supply from new intake and one half from old intake	11.10
March 16 to April 21: Period of epidemic corresponding to use of three quarters of supply from new intake	2.89
April 22 to December 31: Period corresponding to exclusive use of water from new intake	1.03

The epidemic practically ceased about the end of April, as it seems probable that most of the cases which occurred during May were of secondary origin, that is, they were taken from previous cases by more or less direct contact. During the summer of 1904 there was less typhoid in the city than in 1902, which was a favorable year, and much less than in previous years.

At certain times, however, there were slight recurrences of the disease, a few cases suddenly appearing at one time, and the number then falling off, and often becoming zero. In comparing these occasional slight outbreaks with the wind and rainfall records, as was done for the epidemic period, it is noticeable that in some cases the outbreak occurred ten or twelve days after a disturbance of the lake level by a southerly wind or flood. The evidence is not sufficiently strong, however, to trace these cases to the water supply. The increased number of cases during the autumn may be easily accounted for by other causes, and some of them are known to have been imported. It seems possible that a few of the cases in August may have been due to the use of water from the old intake on July 21, but the evidence on the point is not strong.

It must be remembered, always, that typhoid fever is transmitted by other vehicles than water, and that during the autumn, especially, typhoid fever is often present in cities which have

water supplies of undoubted purity. People returning from summer vacations often bring the disease with them, and in large cities this is always an important factor.

INVESTIGATION AND RESULTS.

The typhoid fever epidemic of 1903–1904 led to an extensive investigation of the quality of the water of Lake Erie in the vicinity of Cleveland to determine whether or not the water from the new intake could be considered as healthful and wholesome or whether it ought to be filtered. Filtration of the water from the old intake was also considered, as well as many matters bearing upon future policy in the development of the supply. These studies were made by the writer under the direction of Prof. Edward W. Bemis, the superintendent of water works, and extended from February, 1904, to July, 1905. During the summer of 1904 Mr. Langdon Pearse, and later, Mr. George E. Willcomb, assisted in the work as resident bacteriologists. Mr. George H. Benzenberg, C. E., also acted as consulting engineer. The local health authorities, the city engineer's department, and the United States engineers contributed many valuable data, while the laboratory of the Health Department at the Northwestern University Medical College was placed at our disposal. A full report of this investigation is given in the annual report of the Cleveland Water Department for the year 1905.

The report describes studies of the currents in Lake Erie, both general and local, and the effect of these in diverting the flow of the Cuyahoga River and the sewage of Cleveland toward or away from the water-works intakes. The influence of the wind and other factors is also carefully studied. Samples of lake water and the water in the city mains were analyzed daily for several months, while once each week during the summer special samples were taken from the lake at twenty-five stations located on four parallel lines extending outward from the shore and above and below the city. The farthest of these samples was ten miles distant from the shore. Float experiments were also made in connection with the study of currents. All these data are given in the report.

Time will not permit all of these investigations to be described,

but the results and recommendations, so far as they bear on the general problem, were as follows:

1. The water of Lake Erie at the Old Crib at Cleveland, which was used until April, 1904, often showed by analysis strong evidences of pollution with fecal matter, especially at times when the Cuyahoga River was in flood, and when a southeast wind was blowing. It was a dangerous source of supply and it should never be used again unless filtered.

2. The water of Lake Erie at the New Crib is almost unpolluted by the sewage of the city and may be considered at the present time as reasonably safe from the sanitary standpoint.

3. Occasionally, under certain unfavorable conditions, minute traces of pollution have been detected by analysis in the water at the New Crib and under extreme meteorological conditions, such as may occur at infrequent intervals, it is possible that a slight and transitory infection of the new supply may occur. The danger of this, however, is extremely small and need not be seriously considered at the present time.

4. As the use of the water from the old intake was gradually abandoned and replaced by that of the new supply, the amount of typhoid fever in the city decreased by degrees which corresponded to increasing proportionate amounts of water pumped at the Kirtland Street pumping station; and since the water from the New Crib has been exclusively used the typhoid fever death-rate in the city has been quite low. During the year 1905, this rate was only 18.0 per 100 000, but it should be observed that the meteorological conditions tending to promote pollution of the water have been recently more favorable than during previous years. It is possible that more serious conditions may increase this rate very slightly. On the other hand, as the scattering foci of infection in the region around Cleveland become less numerous, the rate may drop still lower.

5. After the completion of the intercepting sewer system, the danger of pollution of the water at the New Crib will gradually increase as the city grows, until eventually the quality of the water may be affected by it to an appreciable extent. Should the sewage be purified before it is discharged into the lake this would, of course, modify the situation; but to purify the sewage of the

city to such an extent as to remove the danger of infection to the lake water would be more difficult and much more costly than to filter the water. It is not likely that such a purification of the sewage will ever be undertaken.

6. The lake water at Cleveland is not appreciably polluted by other than local sources, although there are faint indications of the influence of the sewage of Lorain and the Black River on the lake water a few miles west of the city. There is no general pollution of the Lake Erie water worthy of being noticed at present or likely to be important in the immediate future. Cleveland alone is responsible for the pollution of her water supply.

7. The water of Lake Erie, near Cleveland, is at times objectionably turbid, not only at the Old Crib but at the New Crib, and even for several miles farther into the lake. This turbidity is due chiefly to clay and silt stirred up from the lake bottom by strong winds, but to some extent it is due to the suspended matter carried into the lake by the Cuyahoga River and other streams. It gives to the water in the city a cloudy appearance, and at times causes some complaint.

8. The water from the new intake does not at present need filtration from the sanitary standpoint, but before many years, when the lake water has become more polluted, filtration will be imperatively necessary in order to protect the health of the city. Furthermore, the standard of quality of public water supplies in American cities is rapidly rising, and consumers are more and more demanding water which, besides being safe, is clear, colorless, an d attractive.

9. The water of Lake Erie at Cleveland is an easy one to purify, either by the method of slow sand filtration or by mechanical filtration. It is naturally devoid of color and its turbidity is seldom excessive. Filtration of this water would render it eminently satisfactory for all purposes, and, except that it is rather hard, it would be second in quality to none of the large supplies of the country. Even its hardness might be somewhat reduced by chemical treatment before filtration. Inasmuch as either system of filtration is applicable, the selection of the one to be used will be governed by questions of engineering and of cost rather than by comparisons of efficiency.

TABLE No. 1.

Population and Typhoid Fever Statistics by Years.

Cleveland, Ohio.

Year.	Estimated Population.	Total Deaths.	Deaths from Typhoid Fever. Number of Deaths.	Deaths from Typhoid Fever. Rate per 100 000.	Per Cent. which Typhoid Deaths were of Total Deaths.
1873	113 025	2 641	68	60	2.57
1874	119 757	2 190	81	68	3.70
1875	126 489	2 962	65	51	2.20
1876	133 221	—	65	49	—
1877	139 953	2 903	82	59	2.03
1878	146 685	2 710	55	38	2.03
1879	153 417	3 038	46	30	1.53
1880	160 146	3 156	70	44	2.21
1881	170 267	3 727	169	99	4.53
1882	180 388	3 156	122	68	3.87
1883	190 509	3 399	123	65	3.62
1884	200 630	3 732	121	60	3.24
1885	210 751	3 574	71	34	1.99
1886	220 872	3 525	113	56	3.20
1887	230 993	4 139	120	52	2.90
1888	241 114	4 414	113	47	2.56
1889	251 235	4 444	185	74	4.19
1890	261 353	5 058	180	69	3.56
1891	273 395	5 204	137	50	2.64
1892	285 437	5 227	167	59	3.20
1893	297 479	5 261	153	52	2.91
1894	309 521	5 663	89	29	1.57
1895	321 563	5 167	117	35	2.27
1896	333 605	4 859	143	43	2.92
1897	345 647	5 007	79	23	1.58
1898	357 689	5 010	121	34	2.10
1899	369 731	5 556	118	32	2.13
1900	381 765	6 104	205	54	3.36
1901*	392 160	5 831	140	36	2.40
1902*	403 032	6 134	133	33	2.17
1903*	414 950	6 799	472	114	6.94
1904	426 992	6 476	204	48	3.15
1905	439 034	6 190	78	18	1.26

*Government estimate.

TABLE No. 2.

Number of Typhoid Fever Deaths in Cleveland, Ohio, During Each Month from January, 1890, to June, 1905.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1890	16	5	11	7	14	24	14	21	21	21	10	10	180
1891	17	11	12	7	9	3	9	15	14	20	13	7	137
1892	7	3	12	5	8	18	29	27	22	21	12	3	167
1893	3	9	14	14	17	15	8	23	15	14	11	10	153
1894	9	7	8	4	1	4	7	14	4	12	12	7	89
1895	7	10	10	10	11	11	5	9	17	17	6	4	117
1896	5	10	19	15	14	10	13	15	16	6	11	9	143
1897	5	2	7	9	6	3	7	12	4	10	9	5	79
1898	6	8	3	5	10	11	6	6	4	21	9	22	121
1899	11	8	15	10	10	10	7	10	9	12	10	6	118
1900	7	14	29	33	22	10	12	27	15	14	8	14	205
1901	15	17	10	14	11	13	15	17	7	9	3	9	140
1902	14	12	12	6	16	13	12	9	11	8	12	8	133
1903	32	23	55	66	51	39	54	42	40	22	20	28	472
1904	12	46	53	28	10	10	5	5	11	12	7	5	204
1905	6	13	5	7	6	3	5	8	7	8	6	4	78
1906	1	8	4	4	8	34	6	8	—	—	—	—	—
Average 90-1904	11	12	18	16	14	13	14	17	14	15	10	10	164

TABLE No. 3.

Number of Reported Cases of Typhoid Fever in Cleveland, Ohio, on Each Day of the Year 1902.

Day of Month.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	0	1	2	1	0	0	2	2	5	0	3
2	2	0	0	0	1	6	1	0	0	0	0	6
3	1	1	1	1	0	0	0	1	2	1	1	1
4	3	3	0	1	0	3	0	2	2	0	0	0
5	2	3	5	0	0	3	0	1	1	0	7	6
6	3	1	1	0	1	0	0	2	2	1	5	0
7	3	0	1	0	3	2	0	1	0	0	1	2
8	2	0	4	0	3	2	1	0	1	0	0	0
9	1	0	4	5	0	0	2	1	0	0	0	2
10	10	0	4	0	0	0	1	1	0	1	0	0
11	4	0	1	0	1	0	3	2	0	0	0	3
12	2	0	0	0	3	1	4	0	1	1	0	0
13	3	4	4	1	5	1	4	1	0	2	2	1
14	1	0	2	0	5	0	0	4	0	1	3	0
15	1	1	2	1	1	1	0	0	1	2	1	3
16	10	1	0	0	1	0	0	13	0	0	0	0
17	1	2	1	0	1	0	8	13	0	1	0	0
18	2	1	0	0	0	0	1	1	0	0	0	1
19	1	0	9	0	2	2	0	0	0	0	0	0
20	1	1	2	1	4	0	1	0	0	0	1	1
21	1	1	1	2	1	0	1	0	0	1	1	0
22	0	0	0	1	4	1	0	2	1	0	1	2
23	0	1	0	0	1	0	1	3	1	0	1	2
24	6	1	3	0	1	1	3	3	2	0	1	1
25	3	3	3	0	6	0	3	3	1	0	2	0
26	4	0	2	0	6	0	1	4	0	1	4	0
27	4	2	2	0	3	0	2	4	0	0	0	0
28	2	1	0	0	1	0	4	9	0	1	1	2
29	0		1	0	0	0	2	0	0	1	3	2
30	1		0	0	0	0	0	1	0	0	0	3
31	2	4	2		2		1	0		0		3
Total	77	27	56	15	60	23	44	74	17	19	35	44

Total number of cases, 491.
Total number of deaths, 133.
Ratio of reported cases to deaths, 3.7 : 1.

TABLE No. 4.

NUMBER OF REPORTED CASES OF TYPHOID FEVER IN CLEVELAND, OHIO, ON EACH DAY OF THE YEAR 1903.

Day of Month.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	3	7	16	6	2	11	10	9	4	0	4
2	3	9	8	21	7	7	8	9	3	14	0	5
3	3	3	27	27	7	16	30	8	2	4	0	0
4	2	2	12	15	9	8	15	5	6	4	1	5
5	2	4	62	25	37	11	11	5	1	5	1	3
6	9	14	7	25	3	15	10	0	1	5	2	3
7	0	1	14	9	31	12	5	0	2	0	2	4
8	8	1	11	19	6	11	13	3	4	0	2	13
9	11	11	16	18	33	11	7	9	27	6	3	4
10	2	6	22	34	17	18	12	8	9	0	8	2
11	2	8	25	18	17	52	13	0	1	1	2	12
12	8	9	14	15	29	17	6	7	30	3	0	15
13	3	0	26	15	17	11	5	3	31	2	2	7
14	10	3	27	19	26	10	5	2	10	2	2	6
15	2	1	16	13	15	8	3	12	4	5	2	12
16	3	1	13	19	15	16	10	17	14	6	2	5
17	7	3	15	1	15	3	28	17	4	0	3	2
18	3	4	33	12	16	8	9	6	2	0	0	3
19	17	34	66	12	21	45	7	13	5	1	2	5
20	3	2	2	8	10	7	7	21	3	1	6	2
21	11	6	21	25	14	5	3	0	4	4	3	2
22	3	4	19	4	24	6	27	4	8	2	1	5
23	6	13	23	51	16	7	6	4	3	6	1	2
24	17	11	22	4	4	4	7	4	11	7	1	0
25	4	25	15	12	4	6	14	6	1	6	1	2
26	16	2	12	16	10	9	14	12	4	2	3	0
27	9	18	43	16	15	8	15	2	4	4	2	2
28	4	18	23	6	12	9	10	3	1	1	1	2
29	1		5	14	12	11	16	4	11	3	0	1
30	7		29	8	3	11	13	7	1	4	1	5
31	4		10		1		2	8		1		0
Total Cases	180	249	644	497	452	361	312	209	216	103	54	133
Total Deaths	32	27	57	59	17	15	57	40	35	21	18	29

Total number of cases during year, 3,443.
Total number of deaths during year, 472.
Ratio of reported cases to deaths, 7.3 : 1.

TABLE No. 5.

NUMBER OF REPORTED CASES OF TYPHOID FEVER IN CLEVELAND, OHIO, ON EACH DAY OF THE YEAR 1904.

Day of Month.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3	8	51	3	0	0	0	0	2	2	0	2
2	1	5	42	6	6	1	1	0	2	0	1	1
3	2	16	27	5	0	0	0	0	0	2	1	0
4	1	4	50	7	3	0	1	1	0	0	2	0
5	6	8	28	5	1	0	0	0	1	0	0	1
6	1	15	5	8	2	0	0	1	3	9	0	0
7	2	12	21	0	2	0	6	0	0	0	1	0
8	11	14	14	7	0	0	0	0	1	1	0	3
9	4	20	13	3	0	0	0	0	1	1	2	1
10	0	25	10	6	4	3	0	0	4	1	0	0
11	1	15	5	6	1	0	0	1	1	1	2	0
12	4	10	8	9	6	0	2	1	3	1	0	0
13	2	7	6	5	0	0	1	5	2	1	0	0
14	2	12	6	3	1	4	0	0	5	1	1	1
15	4	19	16	9	0	0	1	4	0	0	0	1
16	3	26	7	1	2	1	0	2	4	3	3	1
17	1	27	5	2	0	1	1	0	0	0	2	1
18	2	9	6	1	0	1	0	0	1	2	0	0
19	3	17	11	2	0	0	0	1	0	0	2	0
20	1	20	9	3	0	1	2	0	1	0	3	1
21	1	12	9	1	1	1	0	0	1	1	2	0
22	3	13	5	5	1	1	1	4	2	0	2	0
23	3	21	5	0	1	1	0	1	1	0	0	0
24	6	17	10	1	2	0	0	0	2	2	0	1
25	5	32	13	2	0	0	0	2	0	1	0	0
26	4	37	3	2	2	0	0	0	4	0	1	0
27	4	18	3	0	0	0	0	0	1	0	4	1
28	3	15	6	1	1	1	0	0	2	2	7	1
29	4	57	4	0	0	0	0	7	3	0	1	1
30	1		4	0	1	0	0	2	3	1	0	0
31	7		4		1		0	9	0	2		0
Total Cases	95	531	406	102	38	16	16	41	50	34	37	17
Total Deaths	12	46	53	28	10	10	5	5	11	12	7	5

Total number of cases during year, 1 383.
Total number of deaths during year, 204.
Ratio of reported cases to deaths, 6.7: 1.

TABLE No. 6.

Average Analysis of Lake Erie Water.

	Feb. 17 — Apr. 4, 1904.		Feb. 17 — Oct. 1, 1904.	
	Division St. P. S.	Kirtland St. P. S.	Division St. P. S.	Kirtland St. P. S.
Physical Examination.				
Turbidity (Silica scale)	30	13	24	18
Color (Platinum scale)	23	12	18	13
Odor (Arbitrary scale)				
Vegetable	1.7	1.5	1.52	1.31
Moldy	0.4	0.2	0.85	0.13
Oily	0.4	0.0	0.30	0.00 0.05(fishy)
Chemical Analysis. (*Parts per Million.*)				
Nitrogen as Albuminoid Ammonia				
In solution	.118	.094		.103
In suspension	.007	.002		.003
Total	.125	.096		.106
Nitrogen as free ammonia	.011	.019		.022
Nitrogen as nitrites	.004	.003		.004
Nitrogen as nitrates	.06	.02		.06
Total solids	167.5	150.5		156.5
Loss on ignition	24.0	21.2		23.8
Fecal solids	143.5	129.3		135.0
Chlorine	9.9	8.9		8.2
Hardness (total)	103.8	104.3		105.0
Alkalinity	86.7	89.8		88.7
Permanent hardness	17.1	14.5		16.3
Iron	0.58	0.25		0.28
Bacteriological Examination.				
Number per cubic centimeter	12 538	681	8 278	332
Test for B. Coli. (*Per Cent. of Positive Tests.*)				
0.1 cc.	9	0	21	4
1.0 cc.	27	9	55	14
10.0 cc.	59	27	85	44
Microscopical Examination.				
Microscopic organisms per cubic centimeter	160	113	150	117
Amorphous matter	260	250	260	287

DISCUSSION.

Mr. M. N. Baker* (*by letter*). Every paper of the scope and character of this one may justly be regarded as an important contribution to the somewhat slow but successful campaign now being waged against impure water and typhoid fever. With the main conclusions of the author few, if any, will take issue. It remains to be seen whether the good effects which have followed the completion of the new intake will be more lasting than has been the case at Burlington, Vt. Undoubtedly the typhoid death-rate at Cleveland will soon rise again. If the rise be notable, and that would not be surprising, the possible need of water filtration will be brought to the front. It will then be important to determine (as, of course, should always be known) to what extent other causes than the water supply are responsible for such typhoid fever as prevails.

The paper gives no indication of the efficiency of the local health department as regards running down causes of typhoid, and the possible relation of the milk supply, polluted private wells, and privies and flies, thereto. This point is not raised to question the conclusions of the paper regarding the public water supply being the cause of the Cleveland epidemic of 1903–1904, nor the main cause of the long-continued high typhoid fever at Cleveland. It is doubtless true, however, that other sanitary defects at Cleveland were responsible for a considerable amount of the typhoid prior to the completion of the new intake, and for the larger part of the typhoid since the introduction of the improved supply. It is of great importance that these other defects be remedied, first in the interests of the public health, and second, that no injustice be done the water supply when the typhoid rate again rises.

The ratio of cases to deaths indicates, as noted by the author of the paper, that only a small part of the cases were reported in 1902, and by no means all of them in 1903 and 1904. We can never expect to see typhoid brought within reasonable bounds until all cases are promptly reported to the health department and just as promptly investigated by it. It is sad, but true, that in

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but relatively few cities are anything like *all* typhoid cases promptly reported, while in fewer yet are the reported cases properly investigated as to probable origin of the disease. Even where investigations are carried out along fairly satisfactory lines the facts secured are rarely used in the most effective possible way for the prevention of further typhoid due to the same general causes. This is not the place to go into a discussion of the qualities needed in a sanitary or health inspector, but it may be said that the necessary qualities for efficient service are lacking in most of the inspectors now in office, and it must be added that relatively few of their superior officers are so trained that they could intelligently judge and act upon reports based on proper investigations of typhoid cases. This is unfortunate for the engineer and the water-works superintendent, since a failure to disclose the facts, or all the facts, bearing upon epidemic or endemic typhoid often throws unwarranted discredit upon public water supplies.

Finally, is it too much to hope that some day, not too far distant, morbidity and mortality statistics will be sufficiently accurate and complete, and investigations of typhoid cases sufficiently general and efficient, to divide the responsibility for typhoid between public water supplies and the other main contributing causes?

Mr. George C. Whipple (*by letter*). Mr. Baker in his discussion refers to typhoid fever due to other causes than water. This subject has been studied by the local health department of Cleveland with a fair degree of thoroughness since the introduction of water from the new intake. This has resulted in bringing to light several sporadic outbreaks due to milk and other causes. These account in part for some of the larger figures showing the number of typhoid deaths by months during the last year and a half. While the epidemic was in progress, the writer was engaged by the health department to make a study of the vended well waters and spring waters of Cleveland. Samples of each were analyzed, and inspections made of the local supplies. The writer agrees with Mr. Baker that the investigation of typhoid fever from these miscellaneous causes is worthy of very careful study.

Mr. Baker also refers to the laxity of physicians in reporting

cases of typhoid fever. This matter was taken up by the health department during the progress of our investigation, and the agitation of the subject resulted in a decided temporary improvement. It has been found, however, that since the excitement occasioned by the typhoid fever epidemic ceased, the physicians are falling back into their old lax habit of not reporting cases. Studies of statistics in many places have shown that this is nearly always the case, namely, that during the progress of an epidemic, physicians being on the alert, take pains to report their cases when they occur, while at ordinary times, when the cases are comparatively few in number, they do not report them.

A DESCRIPTION OF THE CONCRETE STEEL-REINFORCED STANDPIPE AT ATTLEBOROUGH, MASS.

BY GEORGE H. SNELL, SUPERINTENDENT OF WATER WORKS, ATTLEBOROUGH, MASS.

[*Read September 13, 1906.*]

In presenting this paper it is necessary to state the situation and conditions in Attleborough at the time this standpipe was being contemplated.

It was absolutely necessary that some steps should be taken for better fire and domestic protection, as we had only one force main from the pumping station to the town, a distance of nearly four miles. In case anything should happen to this main it would be nearly as disastrous for domestic supply as for fire. Under existing conditions direct pumping was necessary at every alarm of fire. Our storage consisted of a wrought-iron standpipe 30 feet in diameter and 125 feet high, with a total capacity of 661 000 gallons, that being about the daily consumption. The top of this standpipe is at an elevation of 247 feet, about 142 feet above the ground at the corner of County and Park streets, that being representative of our business section of the town. The iron standpipe was erected in 1890, and although the Attleborough water is one of the best in the state for both domestic and manufacturing purposes, it contains carbon dioxide, so that it attacks unprotected wrought iron or steel, but has very little effect upon cast iron. These were the conditions of our storage system in 1904.

On March 16, 1904, it was clearly presented to the commissioners when a fire occurred in the new Second Congregational Church, not then completed. The alarm was rung in at 5.40 A.M.; direct pressure was immediately put on to the main, amounting to 125 pounds at the pumping station and 100 pounds at the center of the town, which was held for twenty-five minutes, when the pressure dropped to 40 pounds. Fortunately the fire was extinguished at about that time, but we realized that there must

be a serious break somewhere in the system, as the 3 000 000-gallon pump was unable to hold the standpipe pressure. We soon located the trouble, which was a split pipe in the force main, about one mile from the pumping station and three miles from the center of the town. Gates were immediately closed and our standpipe gave us a pressure of 54 pounds. The commissioners, realizing the seriousness of the accident, and what might have happened had not the fire been extinguished when the break occurred, began at once to make investigation as to a larger storage and an additional force main from the pumping station to the town. The commissioners were desirous of building a reservoir of some type to hold 3 000 000 gallons of water, if possible. We employed Messrs. Snow & Barbour, civil and hydraulic engineers, of Boston, to assist us. The investigation was under the personal supervision of Mr. F. A. Barbour.

Owing to the fact that Attleborough is very level, the highest point available in town, locally called Ide's Hill, rises to an elevation of but 250, or 145 feet above the corner of County and Park streets, that being the center of the town. Fortunately, this hill is on a direct line and about half-way between the center of the town and the pumping station. It was evident that a reservoir was not possible if direct pressure was to be obtained. A standpipe was the only alternative; of what height and capacity remained to be considered.

I will not go into details relating to the daily consumption and the number of hours that the pump should be run from an economical standpoint, but will try and explain, as briefly as possible, the reason for building a concrete steel-reinforced standpipe; I will say, however, that after a careful study of both steel and concrete structures Mr. Barbour convinced the commissioners that a standpipe of either type holding 3 000 000 gallons could not be built with safety; that one 100 feet high and 50 feet in diameter, holding 1 500 000 gallons, would be as large as practicable to give the desired pressure. At this writing we know of no structure, of either steel or concrete, of this capacity. We therefore decided that storage of this size would be the largest possible to obtain. With this size, if built in steel, it would be necessary to have the bottom plates $1\frac{3}{4}$ inches in thickness. I believe that

at the present time there are only one or two manufacturers in this country who roll sheets of this thickness.

The experience gained with the former standpipe seemed to indicate that the life of such a structure may be safely estimated at no more than twenty years. The character of the water supply of Attleborough is such that it has more or less corrosive action on iron, which causes a large amount of rust to accumulate in the standpipe. We estimate that there are nearly two tons of rust taken out annually when the standpipe is cleaned; and besides, quite a quantity would necessarily find its way into the mains and services, thereby causing much annoyance in domestic use.

For the last six years all service pipes from mains to cellars have been put in of cement-lined pipe, as we had a great amount of trouble with galvanized pipe, and we find there has been much improvement under these conditions. Thus the quality of our water naturally led to a consideration of other materials for storage rather than steel plates.

As great progress has been made of late in the combination of concrete and steel, the metal being embedded in the masonry and employed to withstand the tensile stresses, we looked carefully and deeply into this method. At this time there had been built standpipes of this type at Fort Revere, in Boston Harbor, that being 20 feet in diameter and 40 feet high*; also one at Milford, Ohio, 15 feet in diameter and 85 feet high; both giving perfect satisfaction. Although neither of these is as large as that proposed for Attleborough, they were sufficient to indicate the possibilities of this type of construction.

We felt justified in asking for bids on a concrete-steel standpipe, also estimates on steel standpipes of same dimensions. The specifications for the concrete steel-reinforced standpipe allowed the bidders to present plans and specifications according to their own ideas of construction, each one specifying the amount of steel to be used, amount of concrete, and factor of safety, with complete plans and method of construction, confining himself to the general design of foundation, standpipe, and gatehouse; the structure was to be guaranteed by the builders for one year from date of acceptance by the commissioners.

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*Described in the JOURNAL, Vol. 19, March, 1905, p. 33.

After a careful study of all plans submitted and methods of construction proposed, we considered that the Aberthaw Construction Company's bid ($34 000) was the one to accept, if any, for the following reasons: Extra steel reinforcement, richness of concrete, method of construction, and complete plans submitted.

We had an estimate on a steel standpipe of the same size for $37 135, making a difference of cost between that and bid accepted, $3 135.

The advantages of a concrete steel standpipe over a steel standpipe are:

First. The cost would be $3 135 less.

Second. No cost of maintenance.

Third. There seems to be no limit to the life of such a structure; or, in other words, is as nearly indestructible as a structure could be made.

The maintenance of a steel standpipe of that size and with our quality of water would be $400 per annum if kept coated on the inside and painted on the outside, and the probable life only twenty years. It would also be necessary to empty the tank annually to clean out the rust and do the painting, which would probably take at least two weeks. During that time water would have to be supplied by direct pumping, which means continuous expense of not less than one hundred dollars per annum. You can see, by this comparison, that there was much in favor of the concrete steel standpipe over the steel standpipe. It seemed to us, in our judgment, it was far better to accept the concrete proposition.

On September 7, 1904, the contract was awarded to the Aberthaw Construction Company, Boston, Mass., under the general specifications prepared by our engineer, which incorporated those of the contractors.

It was early recognized that the greatest responsibility in construction would lie in obtaining watertight walls. The provision of sufficient steel to resist bursting is a relatively simple matter, although many details in joining, bending, and placing the steel required much forethought and labor. The concrete wall is 18 inches thick at the bottom and 8 inches at the top.

In the construction of the standpipe the conditions were care-

fully studied, analyses of the sand and stone were frequently made by sifting samples through a series of sieves, and the materials were proportioned in accordance with the results obtained so as to reduce the voids to a minimum.

The stone was crushed on the work and the concrete mixed by a machine mixer, and in general very good results were obtained both in consistency and uniformity. The foundation of the tank is concrete carried below frost line, a very good bottom of hard pan being found at the depth of seven feet.

In making concrete, sand and crushed rock or clean screened gravel are mixed with the cement. The proportioning of these materials is not or should not be a makeshift process. Up to within a few years, it is true, they were mixed in a more or less arbitrary manner, but at the present time the scientific requirements are better understood, and it has also been found that for the same money better results can be obtained by following this more exact knowledge recently acquired. The scheme of proportioning involves the filling of the voids in the stone with sand, and then slightly overfilling the voids in the sand with cement. The denser the mixture, the better the concrete. To illustrate more fully this method, if you take a barrel of apples you can turn a considerable portion of a barrel of beans into the voids between the apples, and to this mixture considerable rice could be added to fill the voids in the beans, and to this again considerable flour added to fill the voids in the rice. In the same way, in making concrete, an endeavor is made to get the stone in different sizes so that the smaller may fit into the spaces between the larger and thus reduce the voids to a minimum.

After the placing of the foundation, the erection of the steel reinforcement for the first seven feet of the wall was begun. This reinforcement is equivalent to the hooping of a barrel or railroad water tank, except that instead of being on the outside it is embedded in the center of the concrete wall. It is necessarily heavier at the bottom or in proportion to the possible depth of water above. As is usual in engineering structures, the reinforcement of the walls was made several times as strong as is theoretically necessary, or in other words, a factor of safety was used. Three bars lapping 18 inches and held together by clips

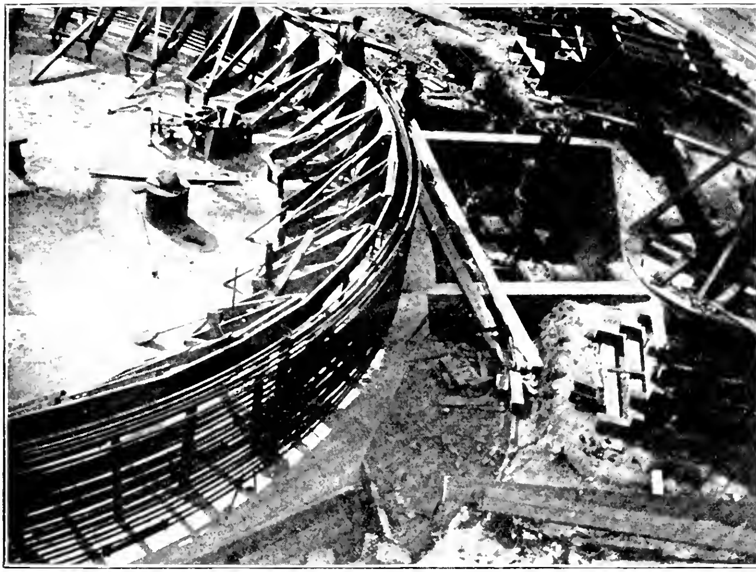


Fig. 1. Gate Chamber and Steel Reinforcement near Base of Standpipe.

Fig. 2. Placing and Ramming Concrete in Wall of Standpipe

were used to make the circle. Near the bottom these bars were placed in two rows, spaced about four inches on centers, horizontally, the spacing increasing with the height until a point was reached where only one row of bars became necessary. The bars were supported vertically by fifteen channel irons with the flanges drilled at proper intervals and small rods run through these holes to carry the horizontal bars.

After erecting about seven feet of steel reinforcement, the inside and outside forms for the concrete were placed in position. These forms were constructed of wood, seven feet high, and two sets were used, so that after the concrete hardened the lower set could be taken down and moved up above the other set.

The circle of the tank was made by having twelve sections in each set, locking them together at the side by iron clamps. After getting the forms in position the concrete was raised by a derrick to the latforms carried on the interior tower, from which it was shoveled into the space between the inner and outer forms and thoroughly rammed and spaded.

After the placing of the concrete another section of steel was erected, the lower set of forms loosened and moved up to a new position, and the wall carried up in this fashion to its full height.

As soon as the first twenty feet was completed it was filled with water, and during the entire construction the tank was kept filled up to within about one foot of the inside forms. This was done to test the tightness of the concrete, also to keep it wet to prevent cracking.

There were leaks developed after we had completed fifty feet. These gradually grew less as the sediment filled the small voids. When completed, with one hundred feet head of water, there were a number of leaks, but on the entire surface only three jets, these spurting out near the bottom, not larger than an ordinary pin. At this time there had been no attempt to put on a watertight coat of plaster on the inside, but it was just as the concrete was put in between the forms. The amount of leakage was practically nothing.

The tank is covered with a Gustavino tile dome and may be said to be a masonry structure throughout.

In many ways the building of the standpipe required the devising of new methods of construction, and the work was consequently slow, the tank not being completed before cold weather set in. This made it impossible to apply the interior coat of plaster before spring.

I wish you to understand at no time has there been a wetting through of this standpipe over more than from 1 to 2 per cent. of the entire surface. This convinces us that a structure of this type can be made absolutely tight.

On December 27, 1905, we put the new standpipe into commission, and continued to use it until May 15, 1906. The leaks during that time were very trifling, although during extreme cold weather we noticed a scaling off on the outer surface at certain points, beginning five feet from the bottom of the tank and extending to a point about fifteen feet from the bottom of the tank. This was apparently caused by pockets or cavities that must have existed on the outside of the steel, probably caused by the slight moving of the forms when the concrete was being placed.

About May 15, 1906, the Aberthaw Construction Company began the plastering on the inside of the standpipe. The first coat had 2 per cent. lime to one part cement and one part sand; the other three coats were composed of one part sand and one part cement. This was floated until a hard, dense surface was produced; then this surface scratched to receive the succeeding coat. This work was done by experts in that line.

Prior to the plastering the entire inside of the standpipe was thoroughly cleaned and then picked. This was done to insure the bonding of the cement plaster to the surface. There were four coats of plaster put on, and we felt reasonably sure that it would be perfectly tight, as great care was used in applying the same. But upon filling the standpipe this did not give us the result we expected, as we had felt positive that we should have an absolutely watertight structure.

At the time the inside work was being done the outside, where the cement had scaled off from the effects of frost, was repaired by digging around the outside row of steel reinforcement, putting on iron clips made of $\frac{3}{4}$-inch by $\frac{1}{8}$-inch iron bolted through, and then cement was forced into the cavities around these clips by

PLATE II.

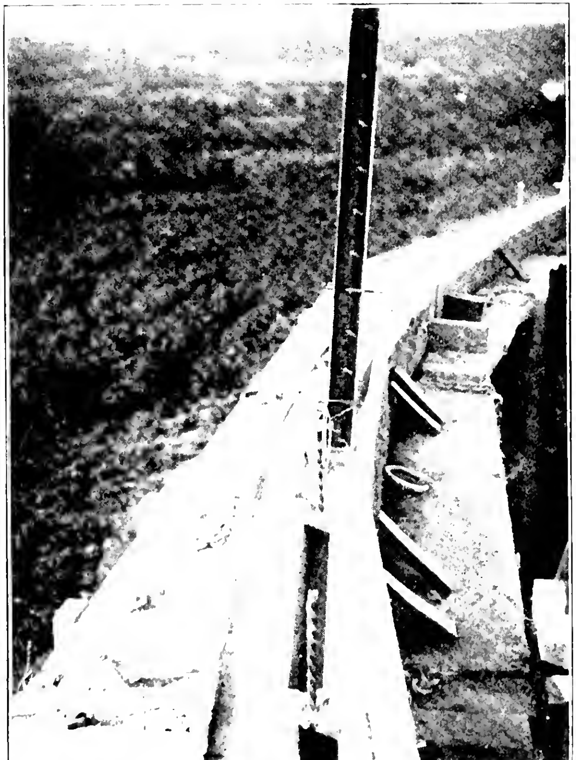


FIG. 1. JUNCTION BETWEEN TWO SECTIONS OF CONCRETE WALL.

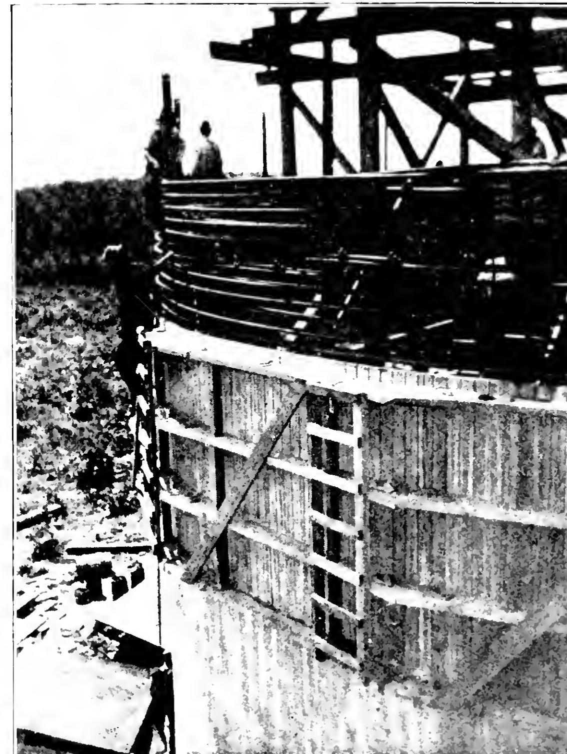


FIG. 2. OUTSIDE FORMS AND STEEL REINFORCEMENT.

throwing it a distance of four or five feet to insure the filling of the voids. This process was continued until the cement covered the entire outer surface so that further plastering could be perfectly bonded; on this surface was placed expanded metal, forced over the clips that stood out horizontally, and then a coat of plaster was carefully troweled over the surface of this metal, and then a coat of metal placed outside of that plastering, the ends of the clips being turned at right angles to hold the same in place. After this the final outside coat was applied, thus making a very firm and compact surface equal to any part of the structure.

After noting the result of the interior plastering, we were satisfied that some other method must be used to make the standpipe perfectly tight under one hundred feet head, at the same time realizing that in a warmer climate we should not hesitate to accept it as it was.

Upon consulting with our engineer and contractor we decided to coat the inside with what is known as the "Sylvester process" wash. I presume many of you are familiar with the same, but for the benefit of those who are not, I will give the formula used on this standpipe:

Dissolve $\frac{3}{4}$-pound Castile soap in 1 gallon of water. Dissolve 1 pound pure alum in 8 gallons of water. Both must be thoroughly dissolved. Before applying to the walls the surface must be perfectly clean and dry; temperature must be about 50° F. First, apply soap at boiling temperature with a flat brush, taking care not to form a froth. Wait twenty-four hours so that the solution will become dry and hard upon the walls, then apply the alum in the same way, at a temperature of 60 to 70° F. Wait twenty-four hours, and repeat with alternate coats of soap and alum.

On the Croton work, four coats of each solution rendered the wall impervious. According to the report made by Mr. Dearborn, a pound of soap will cover about 37 square feet, and 1 pound of alum will cover about 95 square feet. Water may be admitted to the tank as soon as the last coat becomes hard and dry.

This solution has been used with good success on a number of reservoirs, not exceeding a forty-foot head, making them absolutely tight.

In order to test this process we decided to try 35 feet of our standpipe from the bottom up. After applying four coats of the mixture we filled the standpipe full and at 100 feet head we found there were only four leaks in the 35 feet coated. On account of this success, we decided to apply four coats more to this same surface, that making eight coats from the bottom up to 35 feet, and above that distance, four coats; this is not yet completed, but will be within a few days.

There has been no time since the beginning of the structure that the commissioners or engineer have believed that we made a mistake in adopting this type of structure, and we sincerely hope that others will be benefited by our experience.

In closing I will say that I am thoroughly in favor of this type of structure. In constructing a receptacle for water, whether it be a jug or a reservoir, it is a natural desire to build it of stone or masonry. Somehow water tastes better, keeps cooler and cleaner, and the idea of holding water in a masonry structure seems altogether fitting. The aqueducts of Rome were of stone, and it was not until we came to handle water under pressure that metal came into use.

I believe that Attleborough may congratulate itself on its water system, the quality and quantity of the source of supply; in the use of the meter system and the resulting low consumption; in the possession of new cast-iron mains and the small loss of water by leakage; and in the acquirement of a storage reservoir second to none in the world, making possible, in connection with the new pipe lines, a system of fire protection which should and must impress the insurance underwriters to our financial betterment.

DISCUSSION.

Mr. Frank A. Barbour.* I regret that my engagements have prevented the preparation of an adequate discussion of the structure under consideration this evening. However, as you have already listened to the interesting paper of Mr. Snell, and as Mr. Wason, of the Aberthaw Construction Company, is to follow me, it is probable that anything I might have said will be well covered.

The use of reinforced concrete for the Attleborough tank was

* Civil Engineer, Boston, Mass.

Plate III.

Steel Reinforcement Sixty-Five Feet from Ground.

adopted because of the character of the water, which rapidly attacks steel; because of the large size of the tank desired; because of the greater artistic possibilities inherent in a concrete structure; and because of the lesser first cost and cost of maintenance over that of a steel tank.

With the desire to limit the bidders to specialists in reinforced concrete work, and to permit each bidder to use his special type of reinforcement as appeared to him to be necessary and in the best way, bidders were required to submit detailed plans and specifications of the system of reinforcement, the method of construction, and the waterproofing, and to guarantee the structure, in point of safety and watertightness, under penalty of a bond of $10 000, for the term of one year after date of acceptance.

General plans, showing the outward appearance of the tank, the pipe connections and the gatehouse, and general specifications, were prepared by the engineer. Section 4 of these specifications reads as follows:

" And the general intention of these specifications is to specify the size, outward appearance, and the quality of the material and method of its incorporation in the work in so far as the material may affect the life of the standpipe beyond the period for which the contractor is held responsible; — leaving to the contractor the detailed design and choice of type of steel reinforcement, and requiring him to guarantee the safety of the structure and the absence of leakage for the term of one year.

" It is the intention of the Water Board to consider proposals on the basis of cost and on the relative value of the bids as presented from the standpoints of strength and probable absence of leakage as indicated by the specifications describing the proposed method of construction as submitted by the bidder."

The general specifications describe the quality of the cement which should be used, requiring a tensile strength of 185 pounds in twenty-four hours, 600 pounds in seven days, and 175 pounds in 7 days when mixed one part cement, three parts sand, together with the further requirement that the cement mixed one part cement and three parts sand shall develop a strength in twenty-eight days 15 per cent. in excess of that shown in seven days. Fineness was to be such that not more than 5 per cent. would be retained on a sieve with 100 meshes per inch, and not more than

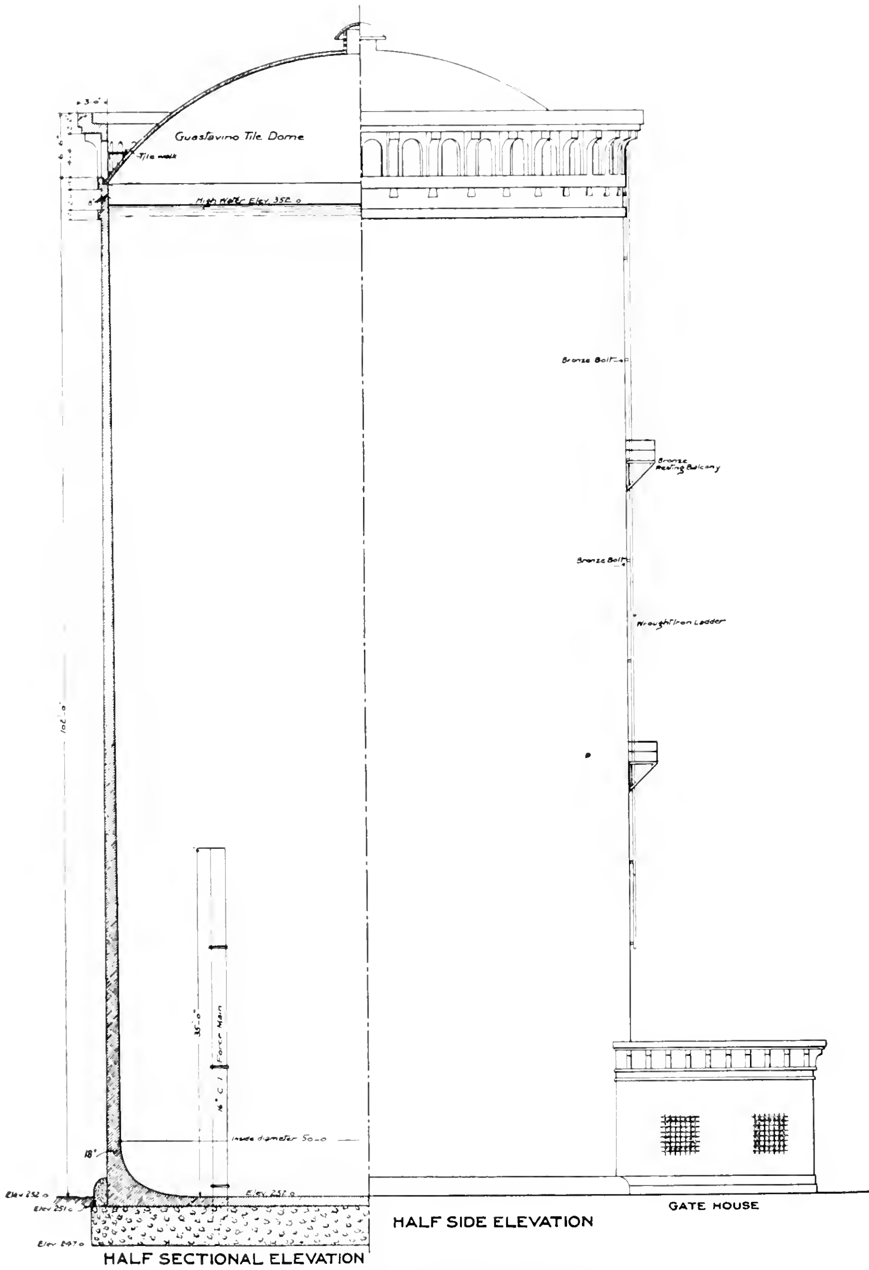
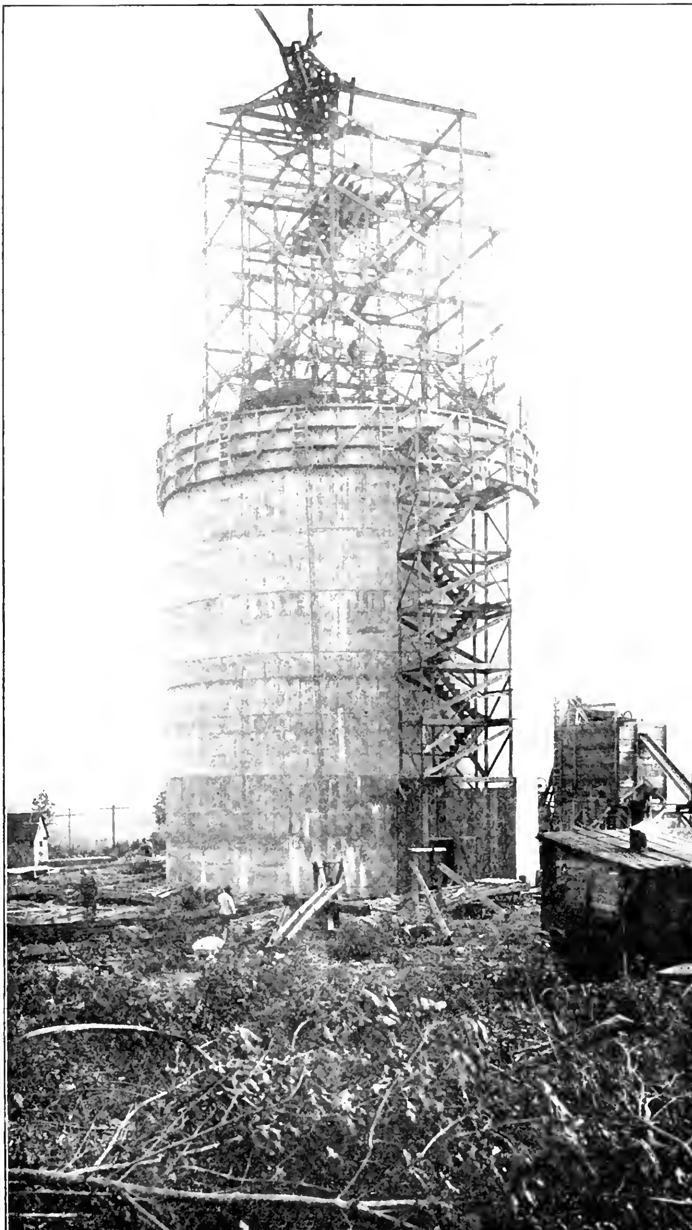


FIG. 1. ATTLEBOROUGH STANDPIPE.



STANDPIPE PARTLY BUILT.

24 per cent. on a sieve with 200 meshes per inch. The standard tests for soundness included the cold test and also the accelerated test in boiling water for three hours.

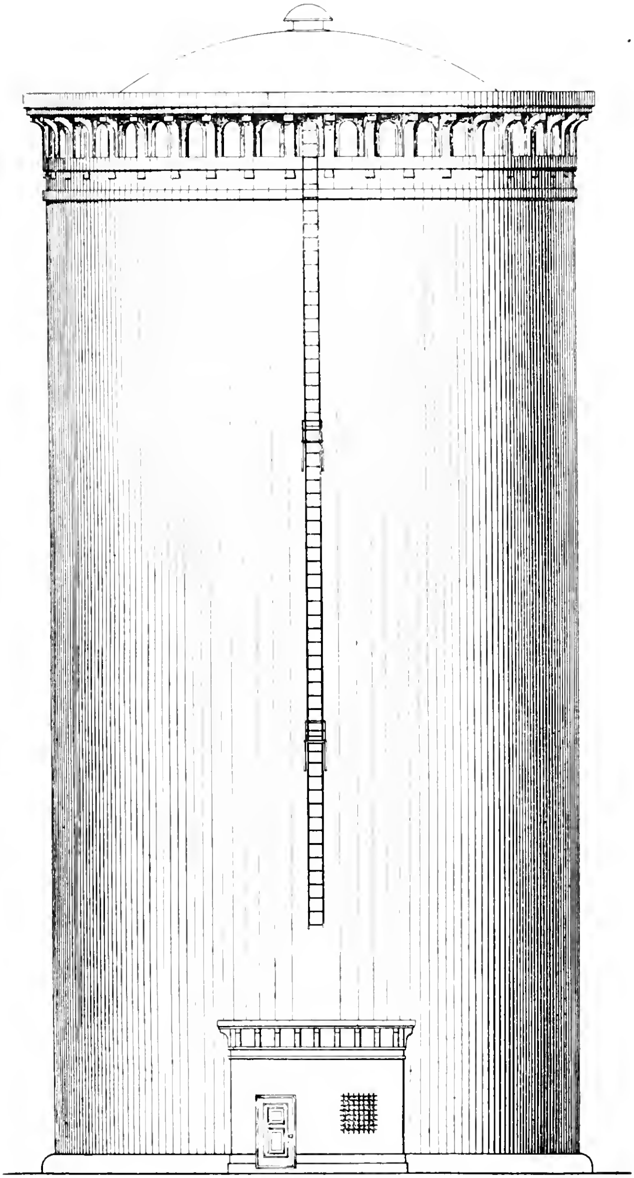
Five bids were received, the total price ranging from $33 679 to $75 000.

As a matter of interest showing various tests in regard to reinforcement, mixture of concrete, and method of waterproofing, it may be worth while to briefly summarize the different propositions.

The lowest bid involved the use of $1\frac{1}{4}$ by $\frac{1}{4}$ inch T-bars as the horizontal reinforcement, with vertical bars 18 inches apart in the walls; no steel in the bottom; horizontal reinforcement with a working stress of 13 000 pounds to 19 000 pounds per inch; bottom to be constructed of concrete, sides of cement mortar, mixed one part cement and three parts sand; horizontal rods joined by soft wire but principal reliance on the bonding of the concrete. Inside plastered with one-half inch coat one part cement, one part sand, and one-half part lime paste.

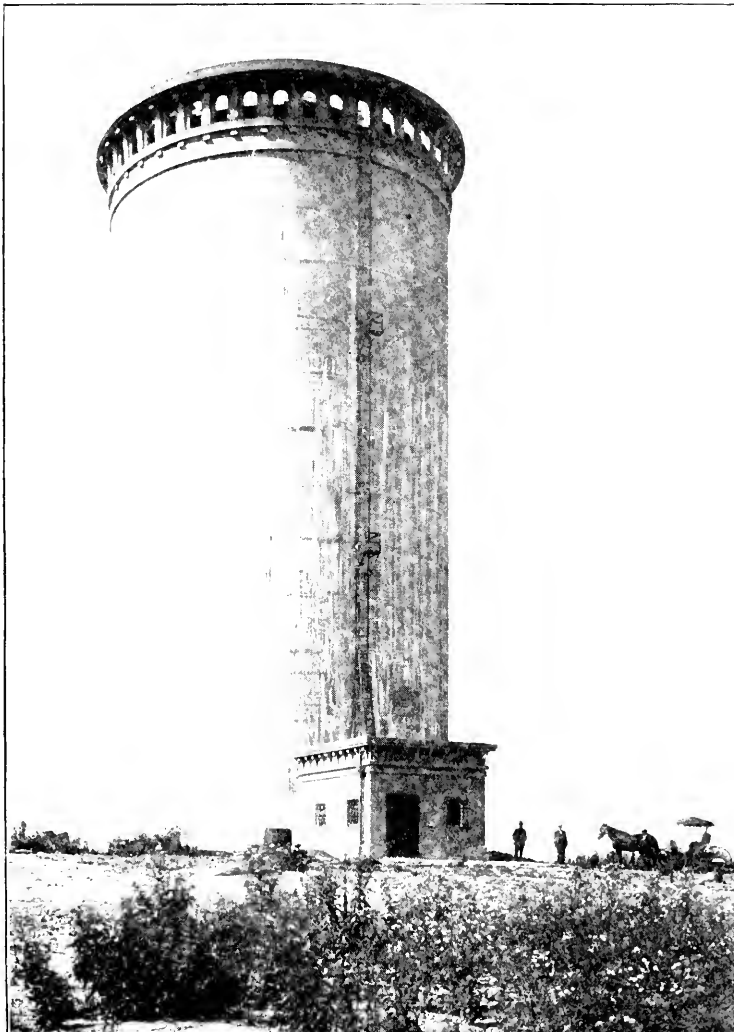
The bid of the Aberthaw Construction Company was based on the use of square, cold-twisted bars, from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches in dimensions, the working stress varying from 13 500 pounds per square inch at the bottom to 8 000 pounds per square inch at the top; the horizontal bars being placed in three rows at the bottom, two rows half way up, and one row at the top; $\frac{5}{8}$-inch square bars being used vertically, 3 feet apart; grill work of steel in bottom for temperature strains; foundations to be constructed of one part cement, three parts sand, and six parts stone. The waterproof work was to be mixed one part cement, two parts sand, and four parts stone, or so as to give an excess of 10 per cent. cement over voids in sand. Inside surface was to be plastered with a special mixture of cement, sand, glue, and alum.

Another bid was based on the use of Thatcher corrugated bars, $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches in dimensions, this reinforcement being used with a working stress of 15 600 pounds per square inch. Vertical bars $\frac{5}{8}$ inches in dimensions were to be spaced 9 inches apart for 80 feet up, and 18 inches apart for the remainder of the height of the tank. Concrete in walls was to be mixed one part cement, two and one-half parts sand, and four and one-half parts stone; no plastering was proposed for walls, but the use of castile soap



FRONT ELEVATION

FIG. 2. ATTLEBOROUGH STANDPIPE.



COMPLETED STANDPIPE.

and alum, applied in three coats, was to be given wall after completion.

A fourth bid contemplated the reinforcement of the tank by Johnson corrugated bars, $\frac{3}{8}$ inches to $1\frac{1}{4}$ inches in dimensions, used with a working stress of 15 800 pounds per square inch; vertical bars, $\frac{1}{2}$ inch square, placed 12 inches apart; concrete in bottom, mixed one part cement, three parts sand, and seven and one-half parts stone; concrete in walls, one part cement, two parts sand, and four parts stone. The noticeable feature of this proposal was the inside and outside facing of the concrete walls with a course of brick, and the placing of a layer of waterproofing between the inner brickwork and the concrete.

The fifth bid proposed a mixture of one part cement, one and one-half parts sand, and three parts stone for the first 50 feet, and one part cement, two parts sand, and four parts stone for the rest of the wall. The reinforcement of Thatcher bars was to be used with a working stress of 14 000 to 19 000 pounds per square inch; plaster to consist of two and one-half coats 1 to 1 mortar, containing soap and alum, and a coating, consisting of lye, alum, and cement, was proposed for the waterproofing of the tank.

It is interesting to note that the working stress varied from 13 500 to 19 000 pounds per square inch; that the concrete varied from a mixture of 1, $2\frac{1}{2}$, 5, to a mortar of one part cement to three parts sand, and that the waterproofing in all cases contemplated some method of surface treatment on the interior face of the wall.

The bid of the Aberthaw Construction Company was accepted.

Briefly, the structure is 50 feet in diameter, 106 feet high from the elevation of inside of bottom of tank to the top of cornice, with walls 18 inches thick at the bottom and 8 inches thick at the top, and covered with a Gustavino tile roof.

The inlet pipe rises to an elevation 40 feet above the bottom of the tank; check valves compel the water to enter through this pipe and leave through the 24-inch pipe at the bottom of the tank, thus insuring circulation. Below the cornice, ornamental pendants of concrete are placed, just above a belt course, and back of these pendants openings were made in the wall, thus providing a large number of spaces for the overflow of water in case of accident.

this water hitting the back of the pendant, striking the belt course, and then falling in a spray to the ground below, thus preventing any danger of accident by washing such as might occur if the overflow were limited to one place. The gatehouse contains two electrically operated gates, by which the standpipe may be cut out and direct service obtained from the pumping station to the town.

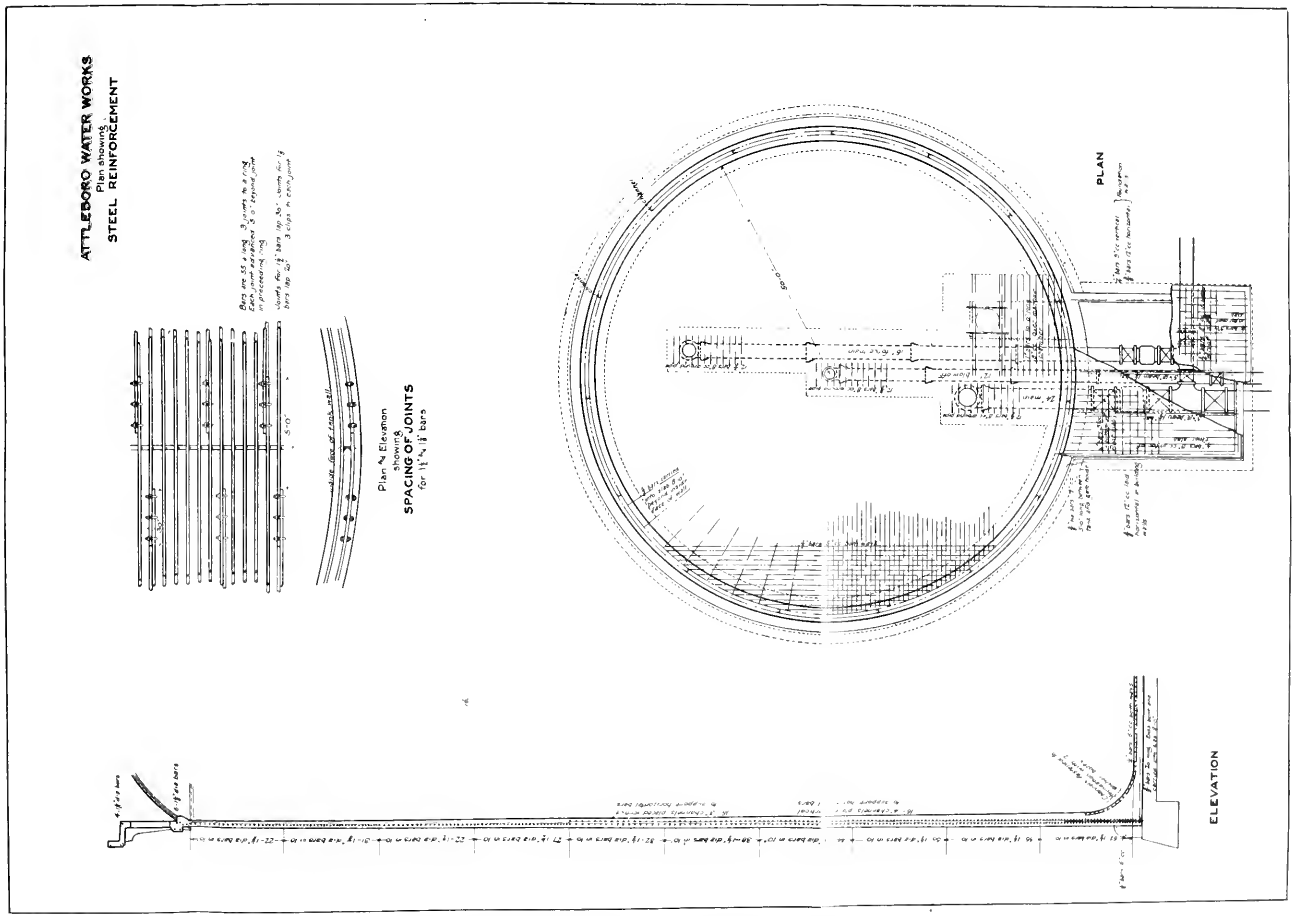
The soil foundation was an excellent quality of hard pan and bowlders.

Describing first the material in the work — the cement was Atlas, especially fine ground, as shown in the following result of tests, for which samples were taken from one barrel in fifteen:

	Tensile Strength.					Condition of Pat Test.		Fineness.	
	Neat.			1 Part Cement 3 Parts Sand.		3 hrs. in Steam.	28 d. in Water.	Percentage Retained on 200 Mesh Sieve.	Percentage Retained on 100 Mesh.
	24 hrs.	7 d.	28 d.	7 d.	28 d.				
Average,	373	594	689	266	358	Perfect	Perfect	14.5	1.0
Maximum,	474	697	793	339	422	Perfect	Perfect	15.8	1.8
Minimum,	203	478	582	199	281	Perfect	Perfect	12.3	.5

The sand used was obtained locally, and had on the average an effective size equal to .30 millimeter, with a uniformity coefficient of 5.6. The stone used, for the most part taken from the immediate vicinity of the work, was of excellent quality, with an average specific gravity of about 2.68. The stone was crushed and passed through screens with openings varying from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches diameter. Immediately below the crusher three bins were placed from which the material could be fed directly into a Smith concrete mixer. The material passing the finest screen was discharged into a sand bin, the medium-sized stone into the second bin, and the coarse stone into the third bin.

Mechanical analyses of the sand and aggregate were made daily, and the material combined so as to reduce the voids to a minimum.



REINFORCED CONCRETE STANDPIPE, ATTLEBOROUGH WATER WORKS.

Considerable information, too detailed for presentation in this paper, was obtained in regard to the value of these mechanical analyses. In this connection it should be stated that while such analyses well justify the expense, all the good results of a proper mixture can be readily discounted in the placing of the concrete. Separation of the aggregate will, to some extent, occur in the discharge of most mechanical mixers, and the final character of the concrete for waterproof work is determined by the maintenance of a thorough mixture up to the actual placing of the concrete in the walls, and the required degree of care in ramming and "joggling" the material to place in and around the walls.

As already stated, it was intended to use square twisted bars, but the impossibility of bending these in a plane necessitated the adoption of some other form, and circular bars of .40 carbon steel, with an elastic limit of 50 000 pounds and an ultimate strength of 80 000 pounds per square inch, were finally adopted. It was also decided to use 1½ inch bars in two rows at the bottom of the wall, instead of the smaller steel bars in three rows, so as to facilitate the placing of the concrete. The steel was delivered in lengths of 56½ feet, three lengths with a lap of 30 inches at the ends making a complete ring.

The use of this .40 carbon steel and the consequent difficulty in bending and holding the bars to the proper circle constituted one of the principal difficulties in the construction of the work. This steel could not be bent in the work and it had to be passed through rolls, which did not, in all cases, develop the true curve out to the extreme ends.

The placing of the steel was begun using the ¾-inch twisted vertical bars as originally planned. It was soon ascertained that in order to maintain the horizontal reinforcement in proper alignment and with the desired vertical spacing, some other method of supporting these members would have to be adopted, and it was determined to use channels, fifteen in the circle of the tank, with the web placed radially and the flanges drilled at proper intervals for the reception of short lengths of ½-inch bars, on which the horizontal reinforcement was hung inside and outside of the channels. In this way the vertical and horizontal spacings of the horizontal reinforcement was insured.

With this method considerable difficulty was encountered in maintaining the 1½-inch bars in alignment, and the work would have been facilitated had additional channels been used. The use of the .40 carbon steel was responsible for this difficulty, and had a softer steel been employed in the work, the erection of the tank would have been rendered much more simple and the final results more satisfactory. This will be referred to later in my remarks.

The regular routine in construction of walls was, first, the erection of the steel for a height of about seven feet or the depth of the form; then the placing of the inside and outside forms; then the filling of the forms with concrete; then a cessation of the work to allow the concrete to set preceding the erection of additional steel. It will be noted that this schedule necessitated a considerable interval between the placing of the different layers of concrete. The feasibility of insisting on the continuous placing of the concrete was one of the debatable considerations in the early days of the work, and one contractor proposed to follow this scheme. Experience, however, early proved the impracticability of continuously placing the concrete in a tank of this size. In smaller structures where a complete outside form can economically be erected to the full height in advance of the work and ribs for the inside form provided, so as to permit the rapid placing of lagging as the work progresses, then it may be possible to place the concrete continuously. In a tank such as that under discussion, the forms must be sectional and the steel must be supported by the concrete as it is erected. This means a cessation of the concrete work between the moving and erection of the forms and steel, which cannot be avoided. By inserting beveled tonguing pieces and by thoroughly washing the joint so as to remove all dirt and laitance, and by covering the joint with a layer of thin grout and mortar before placing additional concrete, watertight joints can be obtained. This was proved, as practically no leakage has occurred at any of the joints.

It cannot be too strongly emphasized that the final outcome in a structure of this kind depends upon the proper placing of the concrete and the maintenance of a uniform mixture up to the actual point of its being deposited in the wall. Success depends

not only on an appreciation by the contractor of the necessary character of the work, but also by the workmen. With a mechanical mixer preparing concrete rapidly and a derrick raising it to the platforms from which it is shoveled into the forms, despite the fact that there were usually a tamper and spader to each shoveler, it was found that in certain places imperfect work would occur. These places were principally in evidence during the first few days of the work, and the quality of the concrete grew rapidly better with the acquired experience of the workmen. In several instances a mixture somewhat too wet was used, with the result that the spading and ramming served to drive the stone to the bottom of the batch being placed, with the result that in these places porous spots occurred. It was clearly proven that a mixture no more wet than would at all times support the aggregate was desirable. Placing concrete in a thin wall with a large part of the section occupied by two rings of steel bars calls attention to the possibility of the stone wedging in and around the bars in such a way as to prevent easy filling of the entire space. For this reason it is believed that round bars are better than square bars because of the greater ease with which the concrete will fill underneath them. In this connection, also, the advisability of using a thicker wall is worthy of consideration. On the other hand, with a thicker wall, certain sections of the concrete must be at a greater distance from the steel reinforcement and such sections, in case of deformation of the steel under tension, may lose the effect of the adhesion between the concrete and the steel, with a consequent cracking of the surface.

In this connection, also, the advisability of using a mortar or a mixture of sand and cement without stone, because of the greater ease and certainty with which it can be placed, may, perhaps, justify the resulting increased expense. It is estimated that, in the tank under discussion, if a mixture of 1 to 2 mortar had been used instead of the 1–2–4 concrete, the cost would have been increased \$2 300; with a 1 to $2\frac{1}{2}$ mortar, \$1 500; and with a 1 to 3 mortar, \$750. This extra expenditure in a structure costing \$35 000 may, perhaps, be justifiable in the decreased liability of imperfect concrete and the greater certainty of an absolute bond between the steel and the cement.

When the walls had reached a height of twenty feet, the tank was filled with water to the elevation of the bottom of the lower form. A considerable leakage at once developed. By plastering the wall, digging out the spots of obviously pervious concrete, the percolation was considerably decreased, but these spots of poor concrete have, until recently, always been more or less in evidence.

I do not intend to enter into a detailed description of the methods used in construction except so far as to explain certain suggestions which I believe may be adopted in future work.

Immediately on the completion of the foundation a hard pine tower was constructed on the interior of the standpipe to an elevation of sixty feet, and on this tower a derrick was erected and maintained at this elevation until the tank was raised to the top of this tower. The tower was then carried up to an elevation of about one hundred and ten feet, and the derrick again raised. This tower was entirely independent of the walls, and served merely to support the derrick and dumping platforms from which the concrete was shoveled into the forms. The existence of this independent structure was unquestionably of advantage in handling the materials, both concrete and steel. The tower, including the raising of the derrick, cost about $1 700.

Outside forms made in sixteen sections, about seven feet high, with horizontal ribs and vertical lagging, and locked together by clamps on the ribs, were provided in two sets, one above the other, the lower one being loosened and placed above the other as the wall progressed upward. These forms were held in place solely by the binding effect of the clamps and the consequent friction on the completed wall. The interior forms were constructed of ribs on which horizontal straight lagging was laid during the progress of placing the concrete, in order to give the spaders a better opportunity to work between the steel rods. The forms were not as heavy as is desirable, and should have been provided with more diagonal bracing and better means of connection and clamping at the ends. The batter which was given the outside of tank increased the difficulty in handling the outside forms, which had to be adjusted from time to time to the varying circumference. It is questionable whether the added effect given

by this batter justified the increased difficulty in handling the forms. It is also believed that it would have paid to cover the outside forms with sheet metal.

One of the conditions to be strenuously avoided in the construction of a concrete structure similar to that under discussion is the possibility of either the steel or the concrete moving after the concrete has been placed and partially set, so as to follow the movement of either the steel or form. With the high carbon steel used in the Attleborough tank and the difficulty of maintaining it in place without the rings being under some stress during the filling of the forms with concrete, it seemed impossible to avoid the chance that some movement of this steel might take place which would result in the formation of a void in the concrete wall. This was also true of the sectional forms. Thus, despite the fact that with each moving of the lower set of forms upward on the wall the circle was carefully taken by steel tape from a center wire on a heavy plumb bob from an independent tower in the center of the tank, it would frequently be found that the forms had moved a fraction of an inch during the placing of the concrete.

It may be worth while to refer to the clips which were used in tying the ends of the steel bars together. These were of the Crosby type, three being placed at each joint. Aside from the increased bond thereby assured, they were necessary with the steel used by the Aberthaw Company in order to tie the ends together and hold them in place during the filling of the forms with concrete. Without these clips the wall never could have been erected. Joints put together on the work, and tested at Watertown Arsenal, proved that the three clips developed the working stress of the steel. As the clips failed by tipping, it is believed that, allowing for the supporting effect of the concrete, the joints in the work will develop the elastic limit of the steel.

As a matter of interest it may be stated that the 1-2-4 concrete in walls cost, approximately, as follows:

COST OF CONCRETE IN WALLS.

	Per Cubic Yard.
Cement	$4.80
Sand and stone	3.90
Mixing concrete	.40
Placing concrete	2.20
Form work	2.65
Total	$13.95

Bending and placing steel cost about $9 per ton, or $2.30 per cubic yard of concrete. There were 770 cubic yards of concrete in the walls, and about 185 tons of steel. The clips, of which about 3 000 were used, cost $1 100.

The work of placing the concrete in the walls, because of various reasons, progressed slowly, and the cornice was not completed until after October 1, 1905. After this the tile roof was constructed, with the consequence that plastering the interior surface was not begun before cold weather had set in. It was attempted to heat the interior so as to permit the completion of this work, but it was found to be impracticable. By agreement with the contractor, the town concluded to use the structure throughout the winter, despite the fact that from the beginning of construction more or less leakage had been in evidence. The principal reason for concluding to keep the structure full of water was the hope that, with use, the leakage would decrease by precipitation of the carbonates in the voids of the concrete. This action has always been in evidence, and frequently leaks will absolutely stop and then apparently, by the breaking of this carbonate dam, subsequently open. It is to be noted that at no time, so far as the amount of water loss is concerned, have the leaks been serious, and if the standpipe were located where freezing weather did not occur, the structure would have been satisfactory even in the condition under which it was used last winter.

The use of the standpipe developed, in certain places, along towards spring, spots of several square feet in area which scaled off the exterior surface, apparently being thrown out by pockets of water which had collected, frozen and expanded. These pockets were unquestionably due to the movement of the steel or forms during construction at a time sufficiently long after the placing of the concrete so that some set had occurred. This

sealing of the exterior surface was confined to areas in the lower fifteen to eighteen feet of the tank. No additional leakage developed, and in all cases the concrete tank, other than these sealed areas, remained in excellent condition.

With the return of spring, the Aberthaw Construction Company undertook the completion of the work, repairing the defacement of the outer surface and plastering the inside. The result has been that, with the completion of the plastering, details of which will, presumably, be given by Mr. Wason, the leakage was decreased to practically a sweating in a limited number of spots. Since then a number of alternate coats of castile soap and alum have been applied, with the consequence that, at the time of last observation made by the speaker, there was no sign of any leakage except in one spot about a foot square, where there was a slight sweating.

The working stress in the steel varies from 8 000 to 13 500 pounds per square inch. At the highest limit the maximum deformation in the steel, due to water pressure, will be about .43 of an inch in the semi-circumference. The adhesion between the steel and the concrete, which is many times in excess of the working tensile stress, prevents movement of the concrete on the steel, but at the surface section most distant from the reinforcement minute cracks have developed, invisible when the wall is dry and only to be found as the tank is drying out or in the manner used by Professor Turneaure in testing beams. This suggests the possible advisability of distributing the reinforcement so as to bring it as near the inside surface of the tank as possible, in such a way that the interior section will partake of the adhesion between steel and concrete. On the other hand, there are some reasons for concentrating the steel as nearly as possible in one plane in order to make certain that all rods are brought under tension uniformly.

As all steel structures economically designed must be based on some deformation, and as in this case the elastic reinforcement is surrounded by a particularly inelastic medium, it would appear that, except so far as the adhesion of the steel and the concrete will counteract the results of stretch in the structure, water-tightness must be obtained by some elastic coating which will cover the minute checking of the surface. It is, of course, un-

necessary to state that these cracks are absolutely microscopic and entirely invisible except as indicated by the narrow wet streak which remains after the tank has practically dried out. It has been suggested that, by adding lime or soap to the concrete, the concrete might be made more waterproof. It is questionable whether this would prevent the checking of the surface, and unless it is possible to use steel with such stress as to bring the structure within the elastic limits of the concrete, waterproofing under higher heads must be obtained by an elastic skin coat. This coat the Sylvester process is apparently able to provide.

Another feature in the design of a structure of this type is the reinforcement connection between bottom and sides. This involves another form of the old problem of an arched dam. With a working stress which will make such a reinforced tank economically possible there will be some stretch in the steel — the bottom is, of course, under compression alone. It would, therefore, seem that radial reinforcement of the bottom running up through the connecting fillet and well into the sides is worthy of consideration.

The above discussion has been intended to call particular attention to the incidental difficulties encountered in the building of the reinforced standpipe. This has been done with the feeling that, in a new field of this kind, by this way alone can progress be made. Because particular attention has been paid to the difficulties encountered and to the possible improvements in future design, the conclusion should not be drawn that the structure is not a success. The engineer, the contractor, and the authorities at Attleborough, have always been perfectly satisfied that no mistake has been made in adopting this type of reservoir.

Summing up the results of experience, it would appear that a soft steel should be used, distributed so as to permit as much greater section of the steel to partake of the effects of adhesion as possible; that extreme care must be taken to prevent movement of the forms and steel during the placing of the concrete; and that in all probability the greater ease and surety of absolutely filling the voids will justify the use of a mixture of cement and sand alone or, perhaps, with fine, clean, screened gravel added, the primary endeavor to be to make the body as a whole as homo-

geneous and impervious as possible, trusting for final waterproofing to a fine coating of some elastic preparation, the necessary attributes of which are apparently fulfilled by the so-called Sylvester process.

MR. LEONARD C. WASON.* Previous to bidding on the reinforced concrete standpipe at Attleborough, Mass., the writer had built a number of watertight cellars, six swimming tanks, and quite a number of cement tanks for various purposes. Most of these were waterproofed entirely in concrete. The greatest head of water in any of them, however, was ten feet. From this experience the writer saw no difficulty in constructing a tank to hold one hundred feet, and subsequent experience has not changed this view.

The specifications and plans were left open for the bidders to design the reinforcement and suggest the mixture of the concrete. In addition to the hydrostatic pressure, allowance was made for ice. By reference to Trautwine's "Handbook," the writer found the maximum theoretical ice pressure would burst the strongest steel tank ever built, and he, therefore, arbitrarily assumed a tension from ice of 30 000 pounds per foot of height on the concrete from top to bottom. The steel was designed for a maximum tension of 18 000 pounds per square inch, of which 13 500 pounds was due to water, the balance to the assumed ice pressure.

Subsequent experience would indicate that there is no trouble from ice, and, therefore, the maximum stress is that due to water only.

As the result of an elaborate series of experiments carried on by the Metropolitan Water Board at Clinton, confirmed by others, and also by the writer's own experiments and experience, it has been determined that mortar made of 1 cement, 2 sand is impervious to water; and concrete approximating 1–2–4, but with from 5 to 10 per cent. excess of mortar over the voids in the stone, would also be waterproof. These were the mixtures that were used, and they proved very nearly waterproof. In selecting material, the writer desired to use gravel screenings, but as none were available, and as there was a large quantity of hard stone

*President Aberthaw Construction Company, Boston, Mass.

in the immediate vicinity, broken stone was used. A good quality of clean, coarse, sharp sand was obtained nearby. Atlas Portland cement was used throughout. A careful mechanical analysis of the sand and stone was made daily in order to get as well-graded sizes of materials, and, therefore, as dense concrete as was possible.

In the design as finally executed the steel reinforcement consisted of 1½-inch diameter plain round bars in two rings from the bottom to a height of 60 feet. Above this a single row of steel was used, which, at 81 feet, was reduced to 1¼-inch diameter. There were 2½ inches of concrete outside of the outer ring, and 4 inches between, so as to give freedom in placing concrete; and the spacing of the bars vertically increased with their height above bottom from 3¾ inches to 8 inches, corresponding with the reduced pressure from water. They were about 56½ feet in length, so that three made a complete ring, and were united at the ends with three Crosby guy-rope clips on a splice of at least 30 inches. They were supported rigidly in place by fifteen vertical 4-inch channels with pins passing through holes punched in their flanges at the spacing on plans, thus giving the exact spacing desired. Each splice was advanced 5 feet over that on the adjoining bars, so that no two splices in either ring came in line; and in one vertical plane there was but one splice in eleven bars.

After the tank was completed a coat of plaster was applied to the inside by the same workmen who had done the concrete. These men were not skilled in plastering.

The plant consisted of a horizontal boiler with engine mounted on its back, driving a Sturtevant roll jaw crusher, which crushes all stone to the size of 1 inch or smaller; elevator, rotary screen, and bins from which stone was drawn into a measuring hopper and fed into a Smith concrete mixer. A circular and band saw were also attached to engine. A heavy tower of hard pine was built in the center of tank, on top of which was a derrick with 40-foot boom handled by engine on the ground, which also had a revolving gear attached. The steel bars were bent by being pulled through a tire bender around a curved form by a steam engine.

The soil gave an exceptionally good bearing. Trenches were excavated below frost line, the pipes laid and embedded in the

concrete mixed 1–3–6. This included 18-inch thickness over the entire area of tank. Upon this base the waterproof concrete of tank began. The floor and a portion of wall about $2\frac{1}{2}$ feet high was cast at one continuous operation in order to avoid all seams and joint. This floor was 1 foot thick and was finished with granolithic troweled on as an integral part of the construction, and reinforced with $\frac{1}{4}$-inch twisted steel bars 6 inches on centers in both directions near the surface in order to resist shrinkage cracks. Quite a number of bars were also embedded in the floor radially and turned up in the wall to bond the two rigidly together.

After completing the floor the tower and derrick were erected; steel was set to a height of $7\frac{1}{2}$ feet, and wooden forms, which were $7\frac{1}{2}$ feet high, made in sections about 11 feet long, were erected. The outer forms were lagged vertically; the inner ones were lagged horizontally, one board at a time, while wall was being filled, so that the concrete was always accessible while being placed. When placing concrete, the work was done in four places around the circumference at once, and as rapidly as possible so as to obtain monolithic work, the entire circumference being kept at uniform height, and the $7\frac{1}{2}$ feet being filled before stopping. At the top a strip of beveled 2-inch by 3-inch wood was put in the middle of wall to form a groove. Before again placing concrete, the top surface was thoroughly scrubbed with water to wash away all laitance, and then the groove and top of the wall was completely coated with neat cement. This joint proved very effective. The operation of placing steel and raising forms took three days, so that the surface on which concrete was placed was quite hard when the work of placing was resumed.

Leakage, etc. — Water was admitted to the tank as it rose in height, the water being kept about twenty feet below the working surface. Numerous small leaks developed, but only two were of sufficient size to squirt beyond the face of wall. From personal observation and cross examination of every one interested in the construction, the writer has been unable to learn that any leak appeared at a high head which did not appear first at a low head. The quantity leaking in some cases increased with the head. The total volume of water lost was small and decreased with time, the leaks appearing to silt up. Were it not for frost

they would not be worthy of consideration. In but three or four places was there any indication by discoloration on the surface that the leakage had rusted the iron. On account of frost, it is objectionable to have walls so saturated with water, as it might lodge in pockets and spall off the surface. This actually occurred in some places last winter. Where there were leaks a white substance was washed to the surface and deposited. By chemical analysis this proved to be almost entirely calcium carbonate, together with some calcium hydrate. This indicates simply that free lime was leached out of the cement. After the plastering was completed on the inside, water was almost immediately admitted, and when drained out, some months later, a deposit of muddy appearance was found on the bottom of tank. This, by analysis, was found to be iron, alumina, sand, and calcium hydrate; it was decomposed cement from which most of the alkali had been removed, doubtless due to water being admitted too soon.

The first coating of plaster was not successful in stopping the leaks. The tank, nevertheless, was put into service and became nearly tight. Last spring it was replastered in a most thorough and careful manner, in the lower twenty feet five coats being used, but with no better result. Subsequently, Sylvester solution has been applied as follows: Thoroughly clean and dry the wall; then a pure Castile olive-oil soap solution was used, 12 ounces to one gallon of water, applied boiling hot. Twenty-four hours later, when the wall was dry, a solution of alum (2 ounces to a gallon of water) was applied at the normal atmospheric temperature; soap and alum washes alternated for four coats of each. This is the method used on the Croton reservoir to waterproof brick walls in 1870. The result, although not perfect, was very encouraging, and four additional coats have been applied, the work not being yet finished. The last time the writer visited the tank, with fifty feet of water, there was but one leak, and this produced only a wet spot the size of the hand.

As a result of this work, the writer believes that the success of this type of construction has been proved. While every means and all information that the present state of the art yielded were availed of, still from the experience gained some further improvements can be made. For instance, a low working stress should

be used in the steel to avoid cracking the cement, and soft steel should be used instead of medium hard; also a change in the number and arrangement of bars. Some improvement could be made in forms to avoid possibility of movement of concrete after being placed while setting which would cause porosity around the reinforcement. A little stronger mortar and less stone could be used to good advantage; and some changes in mechanical plant could be made in connection with the above changes which would simplify the work of erection.

Using a working stress of 13 500 pounds in the steel and a modulus of 30 000 000 pounds, the stretch in semi-circumference of 81 feet when tank is full of water would be .444 inch. It would seem that concrete could stretch this much without cracking, but experience has shown otherwise, as twenty-four hours after water is drawn from the tank, when the walls are drying, so-called "water cracks" show: fine vertical dark lines, with a few horizontal, which indicate that the surface of the cement has been cracked. They are invisible when wall is dry. The plaster coat cracked directly over the cracks in the wall. This would indicate that concrete is an exceedingly rigid and inelastic material. An elastic material is used to bind together a brittle material that will crack at one tenth the stretch steel has at its elastic limit. This is the serious problem of standpipe design. If enough steel is used to prevent cracks, its cost is prohibitive; if a less amount is used, the concrete cracks and leaks. Therefore, as a compromise, use a low stress in steel and an elastic waterproof skin on the inside. The coat of Sylvester solution appears to be sufficiently elastic to form a watertight skin which would stretch without cracking and thus produce the desired result. With the experience in the construction of this tank and a few others which have been built, the art will soon be so perfected as to make this type of construction safe and sane for all locations. In cost such construction can compete for large tanks, but not for small ones.

Lastly, a necessary element of success is to let this type of work only to contractors with large experience, who will appreciate the difficulties and have the technical knowledge and a conscientious desire to master them.

PUMPING WITHOUT ATTENDANCE.

BY S. A. AGNEW, SUPERINTENDENT SCITUATE WATER WORKS, NORTH SCITUATE, MASS.

[*Read September 13, 1906.*]

When I came to read the title that I gave to the troubles that I have endured at my pumping station for the past five years, it struck me as rather a bold title and not very far from misleading; for really, there is no machine that requires closer and more exacting attention than the so-called automatic machine; and particularly is this so of the internal combustion engine, whether it use gas, gasolene, kerosene or what not; for the slightest disarrangement of any of its parts, or the least obstruction to its ignition, or to its flow of gas, throws the whole machine out, and before you can say "Jack Robinson" your engine has slowed down and stopped; and then you have a grand good chance to get to work and get all covered with grease and dirt, finding out your trouble, and one of the best opportunities in the world to exercise the God-given virtue of patience in getting your engine started again.

However, Mr. Kent seemed to think you gentlemen didn't have troubles enough of your own, but must needs share mine, and so I will tell you some of them and then be ready to receive your congratulations — or commiseration — when I get through my story.

I don't suppose there is any call at this time to speak of the general principle of the gas engine; undoubtedly you are all familiar with it, or if not you will find the subject pretty thoroughly covered in the catalogues of the various engines; and as for their good points, just read a few of these circulars and booklets — or better, get hold of a salesman. But if you want to know what thoroughly tantalizing, "cussed" things they are — run them.

The works that I have to do with are comparatively small; we get our water from driven wells and pump into a standpipe on

a hill about three quarters of a mile from the pumping station, and when the standpipe is full, we have about 175 feet head at the pump.

A most serious problem with us is the vacuum we pump against. We have a good supply of good water, but it comes hard and slow, and this summer our vacuum gage has registered as high as twenty-five inches.

We pump our water with two single-acting, triplex pumps (made by the Platt Iron Works), driven direct by two Hornsby-Ackroyd oil engines of sixteen horse-power each; that is, each pump of about a quarter of a million gallons capacity per day is operated by its own engine. And it is with the engine end of it, mostly, that Mr. Kent wishes me to deal to-day.

The great consideration in favor of this kind of engine is on the score of low cost of operating.

Under ordinary conditions these engines can be started by any ordinarily intelligent man; the pumping station can then be locked up, and the man go off about his work for the day, returning at night to shut down, or to oil up if the engine is to be run all night.

This I have done for the past five years; and while there are some drawbacks in such works as ours, where we have only a standpipe twenty-five feet in diameter and seventy-five feet high to pump into,—and unless the standpipe is kept pretty nearly full, people on the high hills get out of water,—still, for small works that can hardly afford an engineer at the pumping station all the time, it is a very cheap way and a very satisfactory way to pump water.

And now as to the engines themselves: The Hornsby-Ackroyd oil engine — the kind we use — is a very simple machine, with very few parts to get out of order; so simple, indeed, that one would suppose it couldn't get out of order. And yet, strange as it may seem, it does.

It is a four-cycle engine, of the hot-surface ignition type.

To start it, the vaporizing cap has to be heated by an ordinary coil lamp until it is hot enough to vaporize the charge of oil that is sprayed into the chamber, and after that the explosions in the vaporizer keep it sufficiently hot to vaporize the oil, without any outside help from the heater.

The engine manufacturers claim that these engines can be started in from five to ten minutes, and possibly they can if everything is in ideal condition; but I have found in practice that it really takes from twenty minutes to half a hour.

This is not all lost time, however, for it ordinarily requires that length of time to get the engine and pump oiled up and generally attended to. For you must know, that if a machine like this is to be left to run itself for hours at a time, and no one to see it, all the care and attention which the ordinary engine has bestowed upon it continuously has in this case to be crowded into the time when the engine is being started; and if this idea is not kept in mind, and any part is overlooked or only carelessly attended to, it is pretty sure to result disastrously.

This, I believe, is the all-important thing to impress on the mind of the man who runs one of these engines. And even after all the carefulness possible, there will things happen that no one can foresee.

For instance, one day I was driving down in the direction of the pumping station, and met an old Irish teamster who was working for me at that time. When the old man spied me coming, he got off his "jigger," and with his hands up to hail me and a look of terror on his face, shouted almost before I was within hearing, "Misther Agnew, dat engine ish goin' like hell." And sure enough, when I got to the station things did look and sound as though they were going in the direction the old man suggested.

A key that held the governor had worked out and the engine was racing. It was rather terrifying to go in and stop it amidst all the noise and clatter of the racing engine and pounding of the pump. But when it was done and the engine looked over carefully, no damage could be found — not even a warm bearing. And so the governor was fixed up and the engine started, apparently none the worse for its race.

And speaking of warm bearings: The greatest and most constant danger in this method of pumping is hot bearings.

Most of the pump bearings are designed to use grease, and on these we use a mixture I make up myself of Albany grease and graphite. Occasionally one of these bearings will warm up a little and the grease melting and running out faster than it

ought gets thrown around by the revolving crank and everything around gets bespattered with that black grease. However, the cups are pretty large to allow for just such happenings, and so no bearing has ever been really damaged on the pump.

On the engine bearings, nothing but oil is used; and I never was fully satisfied with the different methods used for lubricating the different parts, so I have supplemented them with little devices of my own. And even now they are a constant source of anxiety to me, for the piston velocity is pretty high, and let anything occur to obstruct the proper drip, or let them drip too fast and so empty a cup, and there is sure to be something ruined.

There was another difficulty that caused me no end of annoyance at one time, though I am not troubled with it now. The engine made carbon in the vaporizer. It was the funniest thing, too, and I never had the satisfaction of knowing just why it did it, either. This carbon would form in loose balls from the size of a pea to the size of a hen's egg; and when about so much had formed the engine would cool down and stop. It was the most baffling thing with which I ever had to deal.

The engine has stopped as many as three times a day, and each time it stopped the vaporizer cap had to be taken off and the carbon removed — from a quart to two quarts of it. And then at times, for no apparent cause, the engine would run for weeks, and not deposit one particle of it, and then as suddenly begin again.

I did everything I could possibly think of, to remedy it; took the engine all apart, time after time, without any result; for the engine would seem to deposit this carbon just when it saw fit. I had men from the factory who were supposed to be experts, who did the same things I did, and did just about as much good; and the only satisfaction I could get from them (and their bills of expense) was, that the engine ought not to do it.

However, as I said, I don't have this trouble to contend with now, and the only reason I speak of it is because I understand there are members of the association who contemplate installing engines similar to these, and this is one of the troubles they may have.

Now these are some of the troubles I have had in the past. As to the advantages of this method of pumping, as I said before,

the engine can be left entirely to itself, and if it is properly attended to when starting up, will need no attention whatever for ten or fifteen hours.

The time required to start my engine in the morning so that I can go through the day with a comparative feeling of security is about an hour. Say the machine is to run all night also, it will require about another hour in the evening to oil up.

Now, ordinarily, this is all; and you must know that this is not very much time to put on a machine for a twenty-four-hour run.

About twice a week the spray valve, a valve that sprays the oil into the vaporizer, ought to be taken out and thoroughly cleaned, and any dirt or obstruction removed; this takes about ten or fifteen minutes, and can be done generally while the engine is heating up, so that no extra time need be charged up on that account.

For the benefit of the association, I have made some accurate tests during the past month to ascertain the fuel cost of pumping with this kind of engine. Every bit of oil has been measured very carefully, and a close record kept of the hours and minutes the engine has run, and I might say that is the first time I ever attempted to make a really accurate test.

The fuel we use is a cheap fuel oil that can be bought in Boston for about $4\frac{1}{2}$ or 5 cents per gallon in barrel lots. It can be bought considerably cheaper in tank cars and in some other places. I have bought it as low as $2\frac{3}{4}$ cents of an independent oil concern, but on account of increased transportation charges, it cost us about as much as oil bought in Boston at a higher price; and we can get it at shorter notice from Boston. So that for our works the most satisfactory place to purchase is in Boston.

By careful measurement, extending over a considerable period, I found the average consumption of oil to be 1.14 gallons per hour. The average head, including friction, was 180 feet. The amount of water pumped was calculated from the number of revolutions of the pump, and the average displacement per hour was 9 600 gallons, from which I took 5 per cent. for slip.

$$9\,600 - 5\% = 9\,120.$$

This divided by 1.14 gives 8 000 gallons of water pumped per gallon of oil consumed; or, with oil at 1 cent per gallon, the cost

would be $\frac{1}{8}$ of a cent per 1 000 gallons from which you can see what the cost of pumping per 1 000 gallons would be, with any given price per gallon for oil. For instance, with oil at 4 cents per gallon, the cost would be $\frac{1}{2}$ a cent per 1 000 gallons of water; at 6 cents per gallon, the cost would be $\frac{3}{4}$ of a cent per 1 000 gallons; at 8 cents per gallon, the cost would be 1 cent per 1 000 gallons, etc.

The above results put into foot pounds of water pumped per gallon of oil, give 12 031 200 foot pounds per gallon of oil.

I should like to say that in making these tests no special effort was made to secure favorable results or establish records of high efficiency, but rather to secure a record of everyday results. The engine was taken just as it was, and no effort whatever made to put it in better condition than it is every day. I might possibly have secured a higher efficiency had I prepared the engine for it, but it seemed to me that results secured under everyday conditions are of more practical use to us than those secured with conditions ideal, — a state of affairs that doesn't very often exist at most pumping stations.

The labor cost is very small indeed, — two hours per day would be a fair average; but for extras, add, say, 50 per cent. This would be three hours per day for attendance; and I can assure you that this three hours is a generous allowance. Furthermore, three hours will cover a twenty-four-hour run as well as a five- or ten-hour run. In fact, the nearer you can run the engine continuously, the less per hour it costs for attendance, for it takes a man about so long each time, and once the engine is started, it can run fifteen hours just as well as five hours.

That brings me to another thing I want to say right here, in regard to lessening the labor cost: There is a tank under each engine that holds about twenty gallons of oil. You can measure a certain amount of oil and put in this tank — say, $11\frac{1}{2}$ gallons. Start the engine, and leave it, allowing the engine to run down when the oil is used up. This $11\frac{1}{2}$ gallons will run my engine about ten hours. We see, then, there is no occasion for any one going near the pumping station from the time the engine is started one day until it is time for the engine to be started the following day, or whenever it is necessary to start up.

I have done this time and again, especially in the winter, when I have very little help, and so make a considerable saving in my labor bill.

There are other small items of expense to be added to the regular operating expenses, — grease, lubricating oil, etc. But these are small items, for the only new lubricating oil I use is on the piston of the engine. All the oil bearings are lubricated by old oil that has been cleaned in the filter, and if I find my second-hand oil accumulating too fast, I use a little of this on the piston.

Now, gentlemen, I don't know as there is very much more to be said about my pumping station, and how it is run. I have got used to this method of pumping, and am satisfied with it; as to its comparison with steam, I think it far ahead at small works.

There are risks attached to it, and more than that, there is the anxiety to the one who is responsible for the town's water supply; for no matter where one is, if that engine has been left running, one sort of feels it, and can imagine all sorts of things happening that are the source of continual anxiety. And this phase of the matter that cannot be measured in dollars and cents is part of the price you pay for running a plant of this kind.

Naturally, you get used to its running, and it does not weigh so heavily on you as time goes on, and you become accustomed to it. But when I first ran this plant the thing hung over me like some impending disaster; and I would find myself, when getting anywhere near the pumping station, listening to hear the exhaust of the engine, and unconsciously urging my horse to a faster trot to get there before something happened.

If, however, you are willing to put yourself into it and give it your watchful care, you will find it does your work for you in a way that will almost win your love, — certainly, your admiration.

As to my estimate of running this kind of a plant, and what it will do, I have tried to give you a fair idea of what it costs and what it will do, under present conditions. There are, of course, repair expenses that no one can estimate beforehand.

We had an engine once that put us to no end of bother and expense, and I have not included in what I have said any account of the expense either of repairs or labor on that engine, because it seemed to me that there must have been something radically

wrong with it from the first, and it could not with fairness be compared with the ordinary machine of this kind; and so my estimate of running cost has been confined to the two engines now in use at our pumping station.

DISCUSSION.

MR. FRANK L. FULLER.* I should like to ask Mr. Agnew whether he has figured out what it costs him per hour per horse-power to do this pumping?

MR. AGNEW. You can very easily figure that from the foot pounds. I gave about twelve million foot pounds.

THE PRESIDENT. Mr. Tower, of Cohasset, who is a neighbor of Mr. Agnew, ought to be able, as Mr. Agnew says, "to tell us some tales out of school."

MR. D. N. TOWER.† Mr. President, I do not think I can add anything to the very excellent paper we have just listened to. Mr. Agnew seems to have covered the whole ground.

MR. WILLIAM H. THOMAS.‡ I think, Mr. President, that Mr. Tower can give us a little more information in regard to attendance. I do not think he requires as much attendance for his machine as Mr. Agnew reports he does on his, and I wish he would tell us how he operates.

MR. TOWER. I have two engines, and they differ from Mr. Agnew's in this respect, that they are located quite a distance apart, more than a mile, and I run one during the night and one during the daytime. My man who looks after them lives about midway between the two engines. He starts off in the morning, I don't know at what time, probably about half past six, and he passes the reservoir on the way, takes note of the condition of affairs there, and then walks along and stops the engine which has been running all night. He gets down to the other engine at about seven o'clock and starts that up, and then goes about his day's work. About five o'clock in the afternoon he goes to the engine which has remained idle during the day and starts that up and then proceeds to the one which has been running during the day and stops it. That is the way he has been doing all summer.

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* Civil Engineer, Boston, Mass.

† Superintendent of Water Works, Cohasset, Mass.

‡ Superintendent of Water Works, Hingham, Mass.

The cost of attendance is probably about the same as in Mr. Agnew's case, only it covers the two engines. Each engine pumps about nine thousand gallons an hour. I don't know anything more that I can say.

Mr. Agnew. I would like to say that I did give you a good generous allowance for attendance, and did it purposely. The tendency in a paper of this kind is to minimize the " outs "; and when we make a report about our engine's doings, we somehow like to give it a good name and make a good showing. But really, if anything, I have gone the other way in this case and have allowed more time than it actually takes. I, myself, have been to the pumping station, started the engine and left the place inside of twenty-five minutes. It wouldn't pay, probably, to try to do this all the time, and further, I would not want a man of mine to do it at all, for I would be afraid that in his hurry he would overlook something and then it would take more time and cause more trouble to fix up the damage than it would have taken at the start. However, an hour is ample time to start, and in the evening if the engine is running smoothly and you want it to run all night it will take about fifteen minutes to oil up.

Week before last I started up one of my engines Saturday at 3 P.M., that was September 1, and it ran continuously till midnight, Sunday, September 9, a run of two hundred and one hours. Now the only time spent on the engine during this run was to oil up twice a day and this took about fifteen minutes each time, or a half hour per day for attendance. We finally allowed the engine to run down itself by putting oil enough in the small tank to run it to about midnight. So you see that when I allowed that three hours per day for attendance I made it pretty large, and I did it because I had rather be on the safe side than to lead some man into the belief that the engine could run with practically no attendance at all, for it really *does* take some time to look after it.

Mr. Freeman C. Coffin.* I believe I have about recovered from my fright now and can say a few words on this subject. I was, perhaps, responsible for the installation of the first engine of this class which was used for pumping water for a public water supply in this section of the country, the one Mr. Tower has at

* Civil Engineer, Boston, Mass.

Cohasset, and I have advocated the use of this type of power for pumping engines in small supplies for some eight or ten years, and have put in perhaps twenty such plants. I was a little afraid, or, to tell the truth, I was a good deal afraid, when Mr. Agnew began his paper, that he was going to demolish all my theories and show how poor a plant this was for pumping water. I feel much gratified at what he has said, in spite of his troubles, which I believe are incident to all plants, and perhaps show up a little more in an explosion engine plant than in any other, on account of the lack of attendance which is given it.

Of course I do not know so much about them as the men who are running them and looking after them all the time. I have tried to ascertain all I could about them, and while I am not entirely familiar with details, I believe that in most cases the engines have run right along without very much attendance. Of course, in a good many of the plants I have put in, considerable attendance has been given them, but it has not been like the attendance which has to be given a steam engine, by any means; and the expense of these plants, as compared with the expense of a steam engine, is very small, when you are pumping less than two hundred thousand gallons of water a day, or even more, at the price of fuel oil as Mr. Agnew states it. I have always been accustomed, until within a few years, to compute the cost of oil or gasolene at twelve or thirteen cents a gallon, perhaps more, which, of course, makes the fuel cost of one of these plants high, and quite excessive, perhaps, if it were not offset by the saving in attendance.

A kerosene-oil engine, I think, presents a little more difficulty than a gasolene engine. A gas plant, on the other hand, rather less. I put in two gas engines in Charlottetown, Prince Edward Island, where gas could be obtained at a reasonable price and gasolene was very high, and there has been no trouble whatever with those engines. They are used for pumping sewage. At Winchester, Mass., I have put in one gasolene plant and one kerosene plant, and they have never given any serious trouble. One of them was designed to stop itself, in the way Mr. Agnew has explained. There is a measuring tank with a glass tube to gage the quantity of oil. That is in addition to the outside tank

which holds the main body of oil. From the outside tank to this one the oil is pumped by a small hand pump, and by examining his gage the engineer can tell at any time how much oil he has, the idea being to pump enough oil in for the run and let the engine stop itself. In that engine the cooling water for the cylinders is provided by a circulating tank, so that there is no waste of water when the engine is stopped. I don't know how the cylinders of Mr. Agnew's engine are cooled, whether by running water or a circulating tank.

Mr. Agnew. We have a little auxiliary pump bolted to the side of the engine bed and operated by an eccentric on one of the shafts of the engine to pump the water for cooling purposes. As I said at the outset we get our water from driven wells and pump against a considerable vacuum, twenty-five inches. This is quite a pull on the pump and in order to save this good water and also to save such a lift we use water for cooling the engine from a brook that flows back of the pumping station. This water is not suitable for domestic purposes, and there is practically no lift, for the brook is not much lower than the pump.

Mr. Coffin. I was very much interested in what Mr. Agnew said about the efficiency of the pump being a little over 12 000 000 foot pounds to a gallon of oil. That runs up very well indeed, especially when it is considered that that is the ordinary run of the pump and not a special test. On a test of one pump that I put in at Madison, Me., we got 14 000 000, and that I considered very high, but the conditions were quite good, and the conditions make a great deal of difference in the efficiency of a plant of this kind, that is, the head and the amount of water pumped. The conditions at Scituate are apparently very good.

I think this subject of the internal explosion engine is a very important one at this time, because it seems to me that everything points in the direction of the use of these engines for large plants for pumping. The gas producer plant, if it proves to be able to do what it promises to do, is in my opinion going to almost revolutionize the method of pumping water. Mr. Thomas has such a plant which has not been running very long, but I understand it has been very successful so far, and I hope he will tell us something about it. If power can be produced at the rate of one horse-power

per $1\frac{1}{4}$ or $1\frac{1}{2}$ pounds of coal per hour, as I understand the companies who furnish gas-producer plants are ready to guarantee, of course it is very easy for us to see that there is an immense gain over the steam plant, for our best steam plants, our very high-priced high-duty plants in large mills, will not do that. I do not know of any of them that can be depended on to get down to a pound and a quarter. I hope Mr. Thomas will tell us something about the plant which he actually has in use.

Mr. Thomas. I do not think I can say much about it at present, as it is new to us. We pump our water twice, once by a gas-producer plant and once by a steam plant. In our gas-producer plant we burn about 1 000 pounds of coal a day, and pumping the same quantity of water with the steam plant we use a little over 4 000 pounds, so you see there is a little saving in fuel. But the conditions at the two stations are not identical. For instance, at our gas-producer plant, we are pumping against only 16 pounds, and with our steam plant we are pumping against about 80 pounds pressure, so the conditions are not fair for comparison. I think, perhaps, at one of our later meetings I may be able to give a little information in regard to this plant.

Mr. E. H. Foster * (*by letter*). One of the most interesting cases of "pumping without attendance" is to be found at the water works in Peoria, Ill., where there has been in use since 1895 a system of pumping water through auxiliary wells, which was designed and constructed, and later made the subject of letters patent, by Mr. Dabney H. Maury.

This system comes about as close to being "pumping without attendance" as possible, and was a case of invention born of necessity.

The water supply at Peoria is taken from a large open well, 53 feet deep and 34 feet in diameter, sunk in water-bearing gravel near the pumping station. This well gave enough water for the immediate needs of the city, but as the consumption increased an additional supply was soon found to be necessary. Careful surveys were made and test wells sunk with the result that it was decided to build a number of new wells about 800 feet apart and pump over ground to the main well.

* Mechanical Engineer, New York, N. Y.

These wells were about 11 feet in diameter and were large enough to contain a set consisting of a pair of compound centrifugal pumps driven by direct connection to Pelton water wheels, the shafts being vertical. The motors derive their power from a water main connected with the town system near the pumping station, and the waste water from the motors is returned together with the water pumped from the smaller wells through a gravity line to the main well. Weirs for measuring the pumping capacity were fitted at the various wells.

The system has not only been in successful operation since first installed, but has been extended from time to time as the consumption increases.

No attendance whatever is required at the outlying pumping stations, as the motors are stopped and started by opening and closing the valve in the main pumping station.

It is somewhat surprising that this system has not become of more general use. It might at first seem somewhat complicated to take water from the mains to operate the auxiliary pumps, but in reality this will be found to be most efficient, providing the main pumping capacity is large enough to furnish the extra water.

The combined efficiency of the pump and motor is approximately 50 per cent.; thus if the water has been pumped into the main supply at a duty of say 120 000 000 foot pounds, the net duty of the auxiliary plant will be about 60 000 000 foot pounds, which is high for a small unit, particularly when it is considered that no attendance is required.

The system has been found to work very well, and when brought into more prominence will undoubtedly be used where additional supply, filtration or any special service requires a low-pressure pumping plant.

Mr. A. A. Reimer.* Mr. Foster's communication suggests a point I was going to raise, that of pumping by a centrifugal pump with electric motor drive. In East Orange, N. J., we have installed within the past three years a new plant for furnishing about 27 000 or 28 000 people with water from artesian wells, having in use as the main pumps two four-million-gallon cross-compound

* Superintendent of Water Works, East Orange, N. J.

high-duty Snow steam pumps. There are two groups of wells with twenty flowing wells in each group. One group, lying about a mile from the main pumping station, is lower than the main station, and the artesian head is not sufficient to lift the water over the low summit which lies between the pumping station and the second group of wells. In order to pump this second group of wells we are installing at the present time, at a substation near these wells, a centrifugal pump and electric motor guaranteed for five million gallons capacity.

The question has arisen in my mind as to the safety of operating that substation without attendance. You realize that if anything should happen to that large electrical unit, there is going to be trouble. We are protecting the motor with all the best safety devices, but in case of accident, with a mile intervening between the main station and substation, we might be in serious trouble; so I was hoping I might hear some experiences to-day on the part of others who may have similar plants. There is only one that has come within my own observation, and that is at Newton, Mass., which I had the pleasure of visiting some time ago. There the substation is about 1 500 feet from the main station, and it is run with only occasional attendance, the pump being started by means of switches in the main station. That is what we are intending to do, and I wanted to gain a little further light from the experience of others at this meeting, if possible. We are getting ready now to start, and we are going to watch with a great deal of anxiety, I suspect, for a while to find out if things are going to run smoothly. I am not hunting trouble, but I want to keep away from it if I can.

Mr. Fuller. I might say that at Uxbridge, Mass., they have installed a triplex pump with a capacity of about three hundred gallons per minute, which will be run by a General Electric motor, operated by current furnished from the local electric light station. The plant has not been in operation as yet, but we are hoping that it will be possible to run it without having to spend a great deal on the item of attendance. So far as it has been tried it has run very well indeed, and there has been apparently no need of any attention except keeping the oil cups filled and a man going once a day to see if everything is all right. The pump

can be started and stopped from the power station, and the item of attendance apparently will be quite small.

Mr. Coffin. I wish I could give a little more definite information on this subject than I am able to at this time. I put in a plant at Madison, in connection with the engine I spoke of a little while ago, where we wished to take water from a point up stream from the old pumping station, where the water was pumped by power, and to use the power at that station. A generator was put in and the power transmitted to the new pumping station, perhaps three quarters of a mile up the river, above where the sewage of the town came in. There is a triplex pump of about half a million gallons capacity, as I remember, and I have heard no complaint at all about it, so I suppose it has been running satisfactorily and continuously. It was supposed to be started in the morning and left to run through the day, or perhaps longer than that if the consumption of water required it. It is only an assumption that it has been successful, from the fact that it has been doing the work and there has been no complaint and no criticism.

Mr. Fuller. I think, Mr. President, that this comparatively new form of triplex pump is going to be largely used in small plants, because, as has been stated here, the item of attendance is small, the cost of the building is small, no expensive chimney is required and the building can be quite small, and where the electric current can be had at a low rate, or, as in the cases which have been presented to us, where the cost of fuel oil or gas is small, it certainly is going to simplify the pumping question. A good many towns are hardly able to put up an expensive pumping plant and employ a licensed engineer, and there are other items which come in to swell the cost of that kind of plant. These pumps are simple, easily kept in repair; an ordinary man by spending part of his time will keep everything in order, and it seems to me it will be a great help to the average small town if such pumps can be used.

President Sedgwick. In regard to the criticisms which the public may make in any case of failure of the water supply, it seems to me that where there are plants of this kind the superintendent or the water board, or whoever the authority may be

ought at the outset to take the public into his or their confidence and say, " Now we are trying to get along cheaply. Once in a while there may be trouble, and you have got to bear your part of any such hardship as well as the rest of us." And an intelligent community, if educated and taken into confidence in that way, will, I am sure, always respond. That will relieve the engineer or superintendent of some of that care which Mr. Agnew has touched upon, and which is no slight matter. It seems to me that any man who leaves a pump going while he is away must always have it, consciously or unconsciously, on his mind, and that is a pretty serious thing physiologically. In the case of a nervous man it might even mean a breakdown. Therefore in a case of this kind it seems to me that we ought to do what we do so much in America and what they are now doing everywhere all over the world, namely, take the public into our confidence and expect them to coöperate with us, rather than to " keep dark " and tell them, " Oh, it will be all right; don't you worry," and so on; because otherwise when the time of worry comes the man in charge has to bear it all.

In this connection I was reminded of the old rhyme, which some of you will probably remember, about care and its effect on us:

> " Care to our coffin adds a nail, no doubt,
> And every laugh so merry draws one out."

When Mr. Coffin began speaking I was reminded of these lines, for he suggested that he was frightened " nearly to death," and they came to me in this way:

> Care to *our* Coffin adds a nail, no doubt,
> While every 'pump-without-attendance' draws one out.

EXPERIENCE WITH NEW ENGLAND WATER WORKS ASSOCIATION STANDARD SPECIFICATIONS FOR CAST-IRON PIPE AND SPECIAL CASTINGS.

TOPICAL DISCUSSION.

[*September 12, 1906.*]

Mr. Charles W. Sherman. I don't know that I have much to say in the way of personal experience with the specifications, but it may be interesting to the members to know how extensively the sale of these specifications has gone forward. They were adopted at the annual convention four years ago. Immediately thereafter the association commenced to print them in pamphlet form for use by members and others interested. We have had printed at different times 4 000 copies, all of which have been sold at retail by the Secretary, with the exception, perhaps, of 500 copies still in stock. In addition to that we have supplied two parties with 1 000 copies each, one thousand to the National Fire Protection Association, which wished to furnish a copy to each of its members, and the second thousand to the new American Cast Iron Pipe Company, of Birmingham, Ala., which has adopted our specifications as the standard on which to cast all its pipe, and has had them printed with its special cover to circulate as its catalogue. My understanding is that any one who sends to that company for a catalogue will receive a copy of these specifications, simply bound in a special cover bearing the name of the company. In addition to that I have been informed by correspondence that the Lynchburg Pipe and Foundry Company, of Lynchburg, Va., which, I believe, is a comparatively small foundry, confining itself to pipes 12 inches in diameter and smaller, is working on the basis of our specifications. On the whole, it is a very encouraging experience, it seems to me, for so short a time.

When it comes to the matter of buying pipe under the specifications from the old established foundries, the matter is not quite so simple. I was speaking on the subject with Mr. Brackett a few days ago, and he said it seemed to him conditions this year

were such that they compared very nearly with conditions during the coal strike a couple of years ago. At that time we had to buy almost anything which was black under the name of coal, and now we have to buy almost anything which is iron as pipe, no matter whether it is made under our specifications or no specifications. I found very much the same thing, not only this year but last year, in getting small quantities of pipe for one of our western water companies. Whether they were bought from the United States Cast Iron Company or one or two other foundries which pretty nearly dominate the western field, we had to take their special patterns. They would, however, give us the slight comfort of agreeing to comply with our specifications so far as inspection is concerned, but that was about all.

MR. A. A. REIMER. Speaking of trouble with the foundries, I can tell a little experience that we have had in East Orange. After the annual meeting of this association last year, I decided to adopt for East Orange, N. J., the New England Water Works specifications, and since then all our orders have been placed on that basis. The foundries have given us no trouble, with the exception of the United States Cast-Iron Pipe and Foundry Company. This company would always send in a bid for pipe, but would inclose specifications which looked about as much like the New England Water Works specifications as a cow does like a horse, and in consequence their bids have uniformly been rejected; we would not listen to them at all, and this summer I decided to stop asking them to bid. Why they have taken this position is not for me to state. The other foundries with which we have been doing business have agreed to the specifications without any question, and orders have been delivered with reasonable promptness.

REPORT OF THE COMMITTEE ON "UNIFORMITY IN THE DIRECTION OF OPENING HYDRANTS AND VALVES AND IN THE SIZE AND SHAPE OF HYDRANT AND VALVE NUT."

[Presented September 13, 1906.]

Your committee, which was appointed at the New York meeting of the association, in September, 1905, begs to submit the following report:

The lack of uniform standards in matters relating to water supply and fire protection has been long felt by water and fire departments, by manufacturers of appliances connected with these departments, and by water-works engineers, and has caused serious losses to owners and underwriters.

A notable advance has been made in this direction by the adoption by this association of the recommendation of a committee, which reported at the New York meeting in September, 1905, on "Uniformity of Hose and Hydrant Threads."

The matters referred to your present committee, while not of equal importance, are closely related and worthy of careful consideration. The greatest efficiency in the use of apparatus of any kind is dependent upon its simplicity, and uniformity tends to simplicity.

PRESENT CONDITIONS AS TO UNIFORMITY IN WATER WORKS AND FIRE DEPARTMENT APPLIANCES.

The present lack of uniformity is more largely accidental than intentional. In the early days of water-works construction, each city and town was practically a law unto itself in such matters, paying but little regard to the methods employed in other municipalities. The manufacturers supplied the needed appliances in a form to suit their customers, and while better designs and possibly better materials are now employed, the important ele-

ment of uniformity has not yet been entirely secured. It is not surprising that there should have been this lack of uniformity in many particulars, when the great number of manufacturers and the still greater number of users, with their different ideas of what is best, are taken into account.

This report has to do with three matters of great importance, where uniformity does not and never has existed. They stand next in importance to a Standard Uniform Hose Thread.

There is no accepted standard for either the operating nut on valves connected with street mains or for the nut on fire hydrants, and different patterns of each are in use. This is especially to be regretted in the latter instance, because the hydrant wrenches of one fire department will not necessarily fit the hydrants of another. Therefore assistance is often delayed when promptness is of the utmost importance.

Uniformity in each of these two cases ought not to be difficult of attainment, and it is surprising that it does not already exist. No time should be lost in recommending a standard for each.

No uniformity exists as to the direction in which either a hydrant or a street valve turns to open; in some cases they turn to the left, and in others to the right, to open.

There appears to be much greater, if not practically entire, uniformity in the direction of opening of nearly all steam valves, the larger number of small water-works fittings, such as faucets or bibbs, and in almost all water valves found in pumping stations, or connected with pumping engines, which generally open to the left. These far outnumber the valves and hydrants found in the streets, a portion of which, it is to be remembered, now open to the left.

By means of correspondence with manufacturers, a statement has been obtained of the percentage of hydrants and street valves

furnished by them during the last few years which open to the left, and this information is shown in the following table:

	Per Cent. Opening to the Left. Hydrants.	Street Valves.
Ludlow Valve Manufacturing Company (sales for past five years, 5 000 to 6 000 hydrants yearly)	40	40
Coffin Valve Company (as furnished to about 200 cities and towns)	45	45
Eddy Valve Company (since March 1, 1901) . .	84	60
Rensselaer Manufacturing Company	80	60
Chapman Valve Manufacturing Company . . .	50	25
R. D. Wood & Co.	$87\frac{1}{2}$	40
The Fairbanks Company (within the last three years)	11	about 80

The Ludlow Valve Manufacturing Company state that "during the last twelve or eighteen months (letter dated April 4, 1906), the number of hub valves and hydrants which open to the left has greatly increased."

It is safe to assume that no change will ever be made in the direction of opening steam valves and the small fittings just alluded to, which open to the left. They are too numerous and their use so well established that it would be practically impossible to make any change in the direction of opening, even if it should seem desirable.

There can be no doubt that the majority of the hydrants now in use, in New England at least, open to the right. Boston, as the pioneer, inaugurated the practice of opening all hydrants and street valves in this direction, and many of the other cities and towns have adopted the same method. Of late (according to a statement of the Ludlow Valve Manufacturing Company), there has been an increase in the number of hydrants and valves opening to the left.

It thus appears that a majority of all valves, both steam and water, and all small water-works fittings, as well as a portion of the fire hydrants now in use, open to the left.

There is probably no difference in the facility with which hydrants and valves can be opened, whether it be to the right or left.

RECOMMENDATIONS.

After careful consideration of present conditions and an earnest effort to judge wisely as to the future, your committee suggests for the consideration of the association the following recommendations:

1. In new systems all hydrants and valves shall turn to the left to open.

2. All additions and repairs to existing systems of hydrants and valves shall be such that there shall be continued uniformity in the direction of opening, whether it be to the left or to the right. If no uniformity already exists, all new apparatus shall turn to the left to open.

(*a*) A city or town having an established system of water works should continue to install hydrants and valves having the same operating nuts and opening in the same direction as those already in use, unless it has been decided to at once change all old hydrants and valves to the new standard. This principle is imperative and no departure should be made from it. It is unfortunate that entire uniformity was not earlier advocated and adopted. The very rapid increase in water-works appurtenances, great numbers being turned out daily, increases the importance of uniformity.

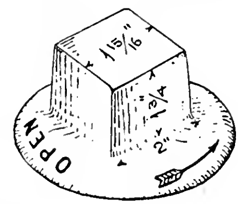
3. All fire hydrants shall have a pentagonal (five-sided) operating nut finished without taper to one and one-half ($1\frac{1}{2}$) inches from "point to flat." The nut socket in the wrench shall be made without taper so as to be reversible.

(*a*) This size and shape of nut is in quite general use and has been recommended by the National Fire Protection Association.

4. An arrow at least six (6) inches long, showing the direction of opening and the words *to open* in distinct letters at least three-quarters ($\frac{3}{4}$) inch high, shall be cast with one-eighth ($\frac{1}{8}$) inch relief, upon the top of all fire hydrants.

5. All valves connected with street mains shall have an operating nut one and fifteen-sixteenths ($1\frac{15}{16}$) inches square at the top, two (2) inches square at the base, and one and three-fourths ($1\frac{3}{4}$) inches high.

6. The operating nut on all valves shall be made with a flanged base upon which shall be cast an arrow, at least two (2) inches long, showing the direction of opening and the word *open* in distinct letters at least one-half ($\frac{1}{2}$) inch high, as shown in the sketch.



The standard direction for opening hydrants and street valves is a perplexing question and there are sure to be differences of opinion. The standards recommended are for new systems and for such others as choose to change. It will be many years before entire uniformity can be secured, and then only by the earnest coöperation of those who believe uniformity to be worth striving for.

FRANK L. FULLER,
FRANK C. KIMBALL,
EDWARD V. FRENCH,
Committee.

DISCUSSION.

MR. FRANK L. FULLER. *Mr. President and Gentlemen:* I regret that I am the only member of this committee present. Mr. Kimball, as you know, has gone to the state of Washington. I had a letter from him a few days ago, in which he said that of course it would be impossible for him to be present at this convention; that he regretted losing so many of our meetings, and he further said that he shouldn't live in Washington all his life unless his life was very short. Mr. French had been away on a vacation, and he regretted very much that he could not be present, and he wished to be remembered to all the members, and desired me to say in connection with this matter of uniformity that he was present at the fire at Fort Fairfield, Me., recently, and that the effect of the lack of uniformity there was lamentable. A steamer came from an adjoining town and was perfectly useless, could do nothing, because it could not connect with the hydrants in the town. That trouble was sought to be remedied by the committee which reported last year in New York in presenting a recommendation for uniform thread for hose and hydrants, which was adopted.

Of course we realize the difficulty of the situation, but we hope the association will adopt these recommendations and that all

the members will use their influence to have this matter of uniformity brought about. We realize that probably there will be difference of opinion, and that all the members will not agree with this report, and we will be glad to hear from those who have different ideas. For the sake of bringing the matter before the meeting, I will move the adoption of this report and the discharge of the committee.

MR. M. F. COLLINS.* Before the motion to accept the report is adopted, I should like to ask Mr. Fuller if he gave the size of nuts on the independent valve stems any consideration, and whether it wouldn't be advisable to have them the same size as on the main valve stem, so you wouldn't have to have, as we do at the present time, a small part attached to the wrench for the small independent hose connection.

MR. FULLER. I am very glad Mr. Collins has brought this matter up. As I understand him, he refers to the nuts which operate the small independent gate valves on a 3-way or a 4-way hydrant.

MR. COLLINS. Yes.

MR. FULLER. It seems to me, Mr. President, that it would be very much too large. Those nuts, as I remember them, are not more than one-half or three-quarters inch square, — half an inch, Mr. Bancroft says. Now I think the committee would be very glad to incorporate a recommendation that these small auxiliary valves be operated by a half-inch nut, if that is the usual size. Perhaps the committee were a little negligent in not looking into this matter, and I am very glad Mr. Collins has brought it forward, for I can see that that is also a matter in which uniformity should exist. By inquiry I think we could find what the common size is, and perhaps it would be wise to adopt that.

MR. COLLINS. I think, Mr. President, that Mr. Fuller is perfectly right about the usual size of this small nut, but we are putting in an independent high-service system at Lawrence, having a pressure of from 125 up to as high as 134 pounds, and in having the hydrants made, we had the heads made the same size on the small independent 2½-inch hose connections that they were on the

* Superintendent of Water Works, Lawrence, Mass.

main spindle, so a man wouldn't have to turn the wrench over at all. I thought I would bring the matter to Mr. Fuller's attention to see what he thought of it.

MR. FREEMAN C. COFFIN.* I should like to ask Mr. Fuller if he has heard any complaint that the stems, as they are made now, are too weak? I have heard some complaint of that kind, and the suggestion that they might be made larger or stronger than in the past.

MR. FULLER. Yes, I think Mr. Coffin is right, that these stems are too small for the wrench which is likely to be used, and apt to twist off. My own idea is that it is much better to screw an independent valve (such as are carried in the hose wagons) on each outlet nozzle of the hydrant, and connect the hose with this valve, rather than have these independent gates which are inside the casing of the hydrant, and which are forever getting out of order. In the excitement of a fire it is very apt to be the experience, I think, that these small stems, being so small, are twisted off and broken, and trouble ensues; when you want to shut them, you can't shut them. But if you have an independent valve, operated by a hand wheel, on each hydrant opening, you avoid this danger. I notice that some of the manufacturers of hydrants place an independent valve on each nozzle of the hydrant. Possibly this matter ought to have received more attention from the committee.

MR. ALEXANDER ORR. In connection with the 4-way and 3-way hydrant, the hydrants which have been shipped to our department lately do not have this auxiliary valve inside the hydrant barrel, but on the outside, being an entirely auxiliary valve with a wheel at the top. That type of hydrant, I understand, is the one which is recommended by the National Fire Underwriters Association, and, in fact, it is the hydrant which was specified by them in some of our work.

MR. GEORGE A. STACY.† While the spindle for the auxiliary valve or independent nozzle, I think, is amply large enough to open or close the valves, the trouble is with the implement we are obliged to employ in opening and closing these small valves. The

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* Civil Engineer, Boston, Mass.

† Superintendent of Water Works, Marlboro, Mass.

wrench is practically the same length and gives the same leverage as that which opens the main gate of the hydrant. You know that all the men who run in the fire departments are not mechanics, and they get the same leverage on the small stem that they do on the main gate. I have had two broken in that way, not because the spindle wasn't strong enough to open and close the valve, but because the man with the leverage he was using was too strong for the spindle. These spindles would do the work if the leverage was reduced to a point where it would be impossible for a man to overcome the factor of safety, but they can't stand the strain where a man with a long wrench uses the same strength to open or close a 2- or a 2½-inch valve as he does to open or close a 6- or 8-inch gate. I think that the valve which is put on the outside of the hydrant, with a wheel giving the leverage adapted for that size of valve, is the proper thing (when placed in a mill yard), as called for by the underwriter specifications and recommended by them for use in their mill equipments. If placed on the hydrants in our public streets, I think there would be danger of their becoming damaged and inoperative by the ever-present small boy and the malicious that are in every community. I think you agree with me that no hydrant maker makes a valve stem which is not amply able to open or close the valve without breaking, and that the trouble is with the wrench.

Mr. Collins. I think this discussion has brought up something which is going to be of some benefit to the association, and while I don't want to impose any more work on Mr. Fuller than is necessary, I think it would be wise to accept, but not adopt, the report to-day, and then to give him a little more time in order to look the matter up and talk with the hydrant men, and in the winter he may have something to suggest to us on the opening of the independent 2½-inch hose connections.

Mr. Stacy. I am not of Brother Collins' mind in regard to not putting any more work on to Mr. Fuller, for I think he has had too easy a time. I was on the committee on uniformity of hose and hydrant threads, and we had quite a job on our hands, and I don't want Brother Fuller to get out of it any easier than we did. He has made what I call an excellent common-, horse-sense report on this matter, as far as he has gone, but I think he can spread

out a little more and take in the other details with a great deal of satisfaction to himself and benefit to the association, and I don't think we ought to adopt this report until he covers the ground more fully.

MR. FULLER. I am sorry Mr. Stacy thinks I have had so easy a time. As I told you, Mr. Kimball is in Washington, and it takes about two weeks to get a letter to him and receive an answer, even if he writes immediately. Mr. Kimball has been very good and said he would help us all he could. Mr. French, as you all know, is an extremely busy man, and acquiesced in my offer to draft a report. So I wrote out the report and sent copies to the other members of the committee. Mr. French was away on his vacation, but he had one of his men come down to my office, a very bright young man, who had had considerable experience in getting out similar papers, and together we went through it, and then I re-submitted it to Mr. French and he thought it was substantially right. Mr. Kimball also sent his approval. I think the points raised by Mr. Stacy and by Mr. Collins are good ones, and the committee will be glad to give proper attention to this matter of independent valves, look into it, and add to this report something in this connection and present it at some meeting next winter. I think the committee would be glad to get the thing into shape and have the matter settled.

MR. A. E. MARTIN.* If the committee wants any more information on this subject, I would suggest that they write to Mr. A. W. F. Brown, water registrar at Fitchburg. I had occasion to visit him a little while ago in regard to some high-service fire protection; he is not only water registrar, but he takes a great interest in the fire department, — runs to about every fire they have and helps out, — and I don't think he would recommend any auxiliary valves at all. In fact, he talked very much against them. He said they were almost always found to be shut when they ought to be open, or open when they ought to be shut, and very often a spindle was broken or otherwise damaged, particularly if the highway department were allowed to use the hydrants. It occurred to me that perhaps the committee might get some useful information from him.

* Superintendent of Water Works, Springfield, Mass.

MR. STACY. I would suggest, Mr. President, that we accept this report of the committee as a report of progress, and request the committee to make a further report at some early meeting next winter.

MR. FULLER. I will withdraw my motion that the report be adopted.

THE PRESIDENT. Then, if there is no objection, the report will be accepted as a report of progress, and the committee requested to continue its work and report finally at some meeting next winter.

MR. CHARLES W. SHERMAN. Before the matter is closed there is one other point in connection with it which, it seems to me, the committee might consider with profit in its future deliberations, and which is of a good deal of interest in connection with one of the works, at least, with which I am connected. In one small water system which we are operating there are valves opening in both directions, and this is not quite so uncommon a thing as might be supposed. I have instructed the superintendent of the works to go over the system and mark, with the most durable white paint he could get, an arrow on the under side of the valve-box cover, showing in what direction the particular valve opens. Most makers of valves also make the standard cast-iron valve boxes which are in general use, and why the covers of those boxes should not be made with large arrows on them, — good, large, prominent arrows, which would show even if the cover got rusty, — I don't see. Of course you would have to buy a supply of covers with right-hand and left-hand arrows, if you had both kinds of valves on the works, but that would be a small matter.

MR. COFFIN. There is one suggestion I should like to make, and I make it modestly, for I haven't thought much about it. It certainly is very desirable that every water works should have uniformity in regard to opening of valves, and all valves certainly should open in the same direction, and it is very unfortunate that matters are in the condition that they are at present. It seems to me it might not be a very expensive matter for towns where there are valves opening in both directions, which desired to adopt a standard, — probably the left-hand standard, — to put on a gear simply to reverse the movement of the valve. I think a

device could be made very cheaply and applied to the flange of the bonnet or hood of the valve without removing the valve or even shutting off the water. One of the gears could be put on in place of the present nut on the end of the stem. I think an apparatus of that kind might be designed at a cost of perhaps less than a 6-inch gate, perhaps not less than a 4-inch gate, and it would obviate any taking up of gates and cutting up pipe lines, etc. I would make the suggestion that the committee consider if anything can be done in that direction.

MR. J. D. HARDY.* Holyoke is one of the places which are unfortunate in having their valves open one way and their hydrants the other way. When they started in to build the works I suppose they didn't think much about that, and we have so many valves and gates now that it would be almost impossible to change them. They are making in Holyoke now what is called the Hercules independent gate to put on the outside of the hydrants. It has a nut, and one-half turn of that opens or closes the valve, and no wheel is required. I don't know what the effect of water hammer would be, but we are putting on quite a number of them now and we have had no trouble from those that are in use so far. They can be easily put on any hydrant, and if they work as they seem to be able to, I think they will be one of the best things that I have ever seen or known of for an independent gate on a hydrant. I don't think much of these things with a small nut on top. I know I put one in one day, and the very next day the firemen went to open it and they broke the nut, disabling the hydrant for that fire. But the Hercules can be readily taken off should it break, though I see no reason why a fireman, even if he loses his head, should break it.

MR. J. C. GILBERT.† The works in our town were put in in 1883 and 1884, and when we called for bids for hydrants, the parties who came forward told us that most hydrants sold at that time opened to the right. The committee — I had the honor of being one of the committee — could hardly see why they should open to the right. We discussed the matter for a number of days, and finally decided that, let others have them as they would,

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* Superintendent of Water Works, Holyoke, Mass.
† Treasurer of Water Works, Whitman, Mass.

we would have ours open to the left, and, therefore, we put in all our hydrants and valves and gates to open to the left, and I assure you we never have been sorry.

I recollect one little incident connected with it. We had a bad break on a pipe line where there were a number of large factories, and we worked all night to get the water on the line so the factories could have it early in the morning. We got through about five o'clock, and I told the foreman that when I went to breakfast I would open one of the gates on the main line before I had my breakfast, so that the factories could get water all right. I did so and then went home, and while I was eating my breakfast a man came up to the house post haste, and said that the factories were in great danger because they had started up steam and couldn't get any water. I immediately left my breakfast and started for the house of the foreman, who also had gone home, and I asked what it all meant. I said: "I opened the gate." He said: "I forgot what you told me, and I sent one of my men up there to open it." It was a mystery to us, and so I said: "Let us go up to the gate," and we went. This man had been working for the city of Brockton, where the gates open to the right; and we found that he had been there and turned down the gate immediately after I had opened it. We have but one gate in the town that opens to the right, and that is not in commission at present, as we have abandoned the well where it is located. It was set by a contractor, and we didn't know that it opened to the right until after it was put in.

Another little incident. Some two years ago we made a trade with the city of Brockton,— when they took water from Silver Lake, — for them to furnish us with water. Of course we had a large gate where we tapped their pipe. It was something like a mile from the center of the village. We got the job all completed, and at the last moment it was decided that we should have a sort of celebration when the water was let on, and I was selected as the man to open the gate. There were, I guess, a thousand people present, and after having pictures taken of all the dignitaries, I placed myself in position to open the gate. It was my good fortune to have one of the Brockton officials standing at my left. After making a short speech, I boldly attempted to open the gate, and

it brought up solid. I was working at it with all my might when the Brockton man touched me on the shoulder and said, "It opens to the right." [Laughter.] It was too late, however, and the laugh was on me. The story got into the local papers and it has always been kept as a joke at my expense.

I never could see any reason myself for opening a gate to the right. What would you think of a manufacturer of screws who made them to turn down by turning to the left? It is just as natural if a man is going to turn a screw to turn it to the right as it is for him to breathe; it seems to be a sort of instinct, and it always seemed to me a very wrong thing to have a valve or a hydrant open to the right.

MR. EDMUND M. BLAKE.* I should like to say a word, Mr. President, along the line suggested by Mr. Sherman. The keeping of careful record plans of pipe lines, connections, hydrants, gates, etc., has advanced a great deal in the last few years, but there are still many cases, in cities where both right- and left-hand gates have been put in, where the record is not quite clear. This has been brought to my own notice in some recent tests which we have been carrying on in some of the large cities with the pitometer. In some cases fires have broken out, and in two particular cases the pressure was very much less than they had expected to get at a given point, and as the pitometer was in service at that time, it was used to investigate to see what the trouble was. In those two cases we found gates, which were supposed to be left-hand gates, which were really right-hand gates, and they were closed and had been that way for five or six years, unknown to any member of the department.

MR. FULLER. In regard to what Mr. Sherman suggests as to putting an arrow on the under side of the cover of the valve-box, would it not be well to put the arrow on the top of the cover as well as on the under side? The only objection I can see to putting it on the top of the cover is that it might possibly get worn off by the action of teams and wheels. If it is put on the under side, I can't see any objection to putting it also on the upper side. I don't suppose it would cost any more in making these covers to have two arrows instead of one, but it seems to me if there is to

* Civil Engineer, Boston, Mass.

be only one, it would be better to have it on top, where a man taking off the cover would naturally see it.

Mr. Sherman. I should certainly advocate casting the covers so as to have the arrow on both sides. My point was that in painting them on the covers, the paint wouldn't last any time at all on the upper surface, and so I told the superintendent to paint them on the under side, and then, of course, a man would have to turn the cover over to see in which direction to open the valve.

PROCEEDINGS.

June Meeting.

"Field Day," June 13, 1906.

Excursion to Charlestown Navy Yard, and by steamer *Philadelphia*, down Boston Harbor and to Nantasket Point.

The following were in attendance:

Members.

S. A. Agnew, F. D. Berry, J. M. Birmingham, C. S. Burns, Jas. Burnie, C. E. Childs, P. M. Churchill, M. F. Collins, E. C. Crosby, Geo. E. Crowell, M. J. Doyle, E. R. Dyer, E. D. Eldridge, I. T. Farnham, J. N. Ferguson, E. W. Gaylord, J. C. Gilbert, A. S. Glover, A. A. Gould, J. A. Gould, J. W. Graham, F. S. Hollis, J. L. Howard, E. W. Kent, Willard Kent, G. A. King, J. W. Lynch, E. C. Levy, F. F. Longley, A. R. McCallum, Hugh McLean, F. E. Merrill, H. A. Miller, E. B. Phelps, E. M. Shedd, C. W. Sherman, J. T. Stevens, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, D. N. Tower, J. C. Whitney, W. P. Whittemore, Geo. E. Wilde, F. B. Wilkins, G. E. Winslow. — 47.

Honorary Members.

W. T. Sedgwick. — 1.

Associates.

Builders Iron Foundry, by A. B. Coulter; Chapman Valve Mfg. Co., by Edward F. Hughes; Fred C. Gifford; Hersey Mfg. Co., by Albert S. Glover; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by A. R. Taylor; National Meter Co., by J. G. Lufkin; Platt Iron Works Co., by F. H. Hayes; Rensselaer Mfg. Co., by C. L. Brown; Ross Valve Co., by Wm. Ross; Thomson Meter Co., by E. M. Shedd; Union Water Meter Co., by W. F. Hogan; R. D. Wood & Co., by W. F. Woodburn; Henry R. Worthington, by Samuel Harrison. — 14.

Guests.

D. L. Agnew, Scituate, Mass.; C. O. Bourne, Charlestown, Mass.; F. L. Cadou, Vincennes, Ind.; Miss S. Chambers, Miss M. Ebert, Buffalo, N. Y.; Miss Nellie DeGreefe, Amsterdam, N. Y.; A. F. Estabrook, Leicester, Mass.; Mrs. J. N. Ferguson, Boston, Mass.; C. O. Galvin, E. F. Garby, Worcester, Mass.; Mrs. John A. Gould, Newton, Mass.; Edward Hanlon, Cohasset, Mass.; W. C. Hopper, Paterson, N. J.; Mrs. J. L. Howard, Boston, Mass.; F. S. Inman, Akin, N. Y.; R. A. Jones, Waltham, Mass.; Mrs. E. W. Kent, Woonsocket, R. I.; A. A. Longley, Washington, D. C.; Miss K. S. McCarthy,

Boston, Mass.; Mrs. H. A. Miller, Newton Highlands, Mass.; Miss Norwell, Chicago, Ill.; Mrs. Noyes, Gloversville, N. Y.; Mrs. E. B. Phelps, Boston, Mass.; Chas. Rollins, Watertown, Mass.; Chas. W. Ross, Mrs. Chas. W. Ross, Newton, Mass.; Mrs. G. M. Sargent, Kansas City, Mo.; Capt. Sears, Mrs. Sears, Lynn, Mass.; Mrs. E. M. Shedd, Somerville, Mass.; Miss Stizil, Chicago, Ill.; Mrs. R. J. Thomas, Lowell, Mass.; E. A. Winchester, Malden, Mass.; Mrs. G. E. Winslow, Waltham, Mass.; Mrs. B. M. Wood, Kansas City, Mo.; — 35.

[Names counted twice, — 2.]

Meeting was called to order on board the steamer by Vice-President Jos. M. Birmingham. Secretary Willard Kent read applications for membership from the following persons:

For Resident Member: Dr. Gardner T. Swarts, Providence, R. I.; Charles E. Childs, Somerville, Mass.; E. C. Crosby, Brattleboro, Vt.,

For Non-Resident Member: George M. Bacon, Salt Lake City, Utah; S. J. Rosamond, Fort Smith, Ark.; Robert J. Harding, Hudson, N. Y.; Charles L. Fox, Pittsburg, Pa.; A. W. Shaw, Brandon, Manitoba.

These applications were approved by the Executive Committee. It was voted that the Secretary cast a ballot for the applicants, and he having done so, they were declared duly elected to membership.

There being no further business, the meeting adjourned.

Twenty-Fifth Annual Convention.

Fabyan House, Fabyans, N. H.,

September 12, 13, 14, 1906.

The Twenty-Fifth Annual Convention of the New England Water Works Association was held at the Fabyan House, Fabyans, White Mountains, N. H., on Wednesday, Thursday, and Friday, September 12, 13, and 14, 1906.

The following members and guests were registered:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, J. E. Beals, F. D. Berry, J. M. Birmingham, F. E. Bisbee, E. M. Blake, George Bowers, James Burnie, C. E. Chandler, J. C. Chase, F. C. Coffin, M. F. Collins, J. H. Cook, G. K. Crandall, C. E. Davis, J. J. Desmond, M. J. Doyle, Bartholomew

Dwyer, E. R. Dyer, C. H. Eglee, E. D. Eldredge, C. R. Felton, A. M. French, F. L. Fuller, J. C. Gilbert, W. J. Goldthwait, X. H. Goodnough, F. W. Gow; J. W. Graham, P. T. W. Hale, J. D. Hardy, H. R. Johnson, W. S. Johnson, Willard Kent, Patrick Kieran, G. A. King, Morris Knowles, F. H. Luce, Hugh McLean, H. V. Macksey, A. E. Martin, F. E. Merrill, H. A. Miller, J. T. Miller, F. L. Northrop, Alexander Orr, Washington Paulison, C. E. Peirce, T. A. Peirce, E. B. Phelps, A. A. Reimer, E. M. Shedd, C. W. Sherman, G. H. Snell, H. W. Spooner, J. F. Sprenkel, G. A. Stacy, G. T. Staples, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, L. L. Tribus, C. K. Walker, E. L. Wallace, C. S. Warde, J. C. Whitney, G. E. Winslow, I. S. Wood, G. W. Wright, L. C. Wright. — 74.

Honorary Members.

William T. Sedgwick, F. W. Shepperd.— 2.

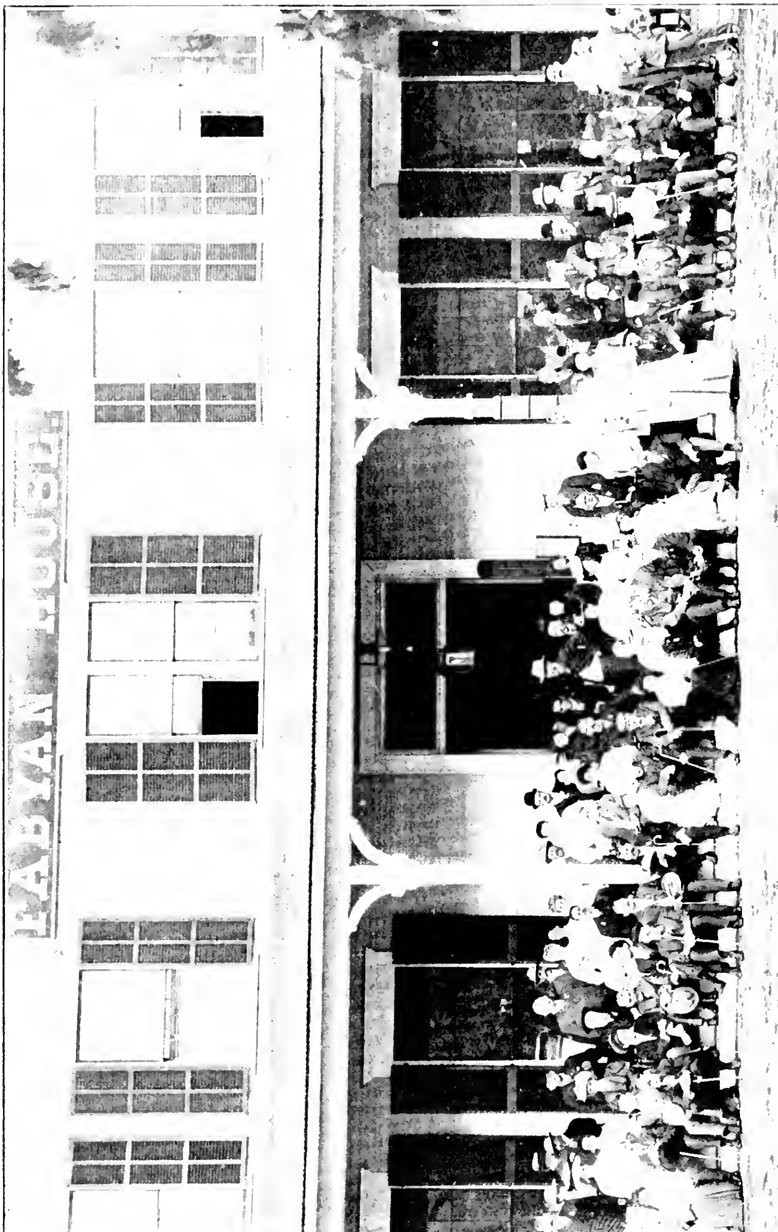
Associates.

Anderson Coupling Co., by Chas. E. Pratt; Ashton Valve Co., by C. W. Houghton; Builders Iron Foundry, by A. B. Coulters; Chadwick-Boston Lead Co. by C. N. Fairbairn; Coffin Valve Co., by H. L. Weston; The Fairbanks Co., by F. A. Leavitt and Chas. H. White; Garlock Packing Co., by J. E. Case; Hart Packing Co., by Horace A. Hart; Hersey Mfg. Co., by H. D. Winton and H. V. Macksey; International Steam Pump Co., by Sam'l Harrison; Jenkins Bros., by J. D. Stiles; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by O. B. Mueller and Geo. A. Caldwell; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Norwood Engineering Co., by H. W. Hosford; Pittsburg Meter Co., by F. C. Clifford; Rensselaer Mfg. Co., by C. L. Brown; Ross Valve Co., by William Ross; A. P. Smith Mfg. Co., by Fred Whitcomb; Thomson Meter Co., by Edw. M. Shedd; Union Water Meter Co., by F. L. Northrop, Edw. P. King and Chas. F. Merrill; Water Works Equipment Co., by W. H. Van Winkle; R. D. Wood & Co., by Wm. F. Woodburn.— 31.

Guests.

Mr. M. K. Murnair, Biddeford, Me.; Miss Dyer and Miss Robinson, Portland, Me.; Mrs. John C. Chase, Derry, N. H.; Mr. and Mrs. W. M. Gates, Nashua, N. H.; Mrs. E. L. Wallace, Franklin, N. H.; Mrs. T. J. Baker, Johnson, Vt.; Mr. Browley, conductor Mt. Washington Railway, Fabyans, N. H.; Mrs. G. H. Snell, Attleborough, Mass.; Mrs. Charles W. Sherman, Belmont, Mass.; Mrs. H. A. Hart, Mr. and Mrs. P. H. Gallaher, Mrs. Wm. S. Johnson, Miss Florence Kimball, Mrs. J. D. Stiles, Mrs. H. H. Kinsey, Mrs. H. V. Macksey, Mrs. Sam'l Harrison, Miss Joan M. Ham, Mr. L. C. Wason, Mr. T. P. Taylor, Boston, Mass.; Mrs. Charles R. Felton, Brockton, Mass.; Mrs. C. H. Eglee, Brookline, Mass.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; Mrs. D. N. Tower, Mary P. Tower and Bessie L. Tower, Cohasset, Mass.; Mrs. George T. Staples, Miss G. M. Staples, Dedham, Mass.; Mrs. Patrick Kieran,

Plate I.



Convention of N. E. W. W. Association, September, 1906.

Fall River, Mass.; Mrs. H. W. Hosford, Mrs. W. A. Stevenson, Florence, Mass.; Miss Elenor R. Goldthwait, Mrs. C. M. Gregory, Marblehead, Mass.; Mrs. H. W. Spooner, Gloucester, Mass.; George N. Cross, Haverhill, Mass.; Mrs. A. M. French, Holyoke, Mass.; Mrs. Wm. H. Thomas and Miss Helen A. Thomas, Hingham, Mass.; Mrs. J. J. Desmond, Lawrence, Mass.; Mrs. George Bowers, Miss Helen E. Bowers, Mrs. R. J. Thomas, Miss C. Walsh, Miss K. Walsh, M. E. Murkland, Lowell, Mass.; Eleanor A. Barden and H. B. Sylvester, Middleboro, Mass.; Buckingham Miller, Newton Highlands, Mass.; Mrs. S. A. Agnew and Miss Hattie F. Seaverns, North Scituate, Mass.; Mrs. E. D. Eldredge, Onset, Mass.; Miss S. C. Berry, A. W. Danforth, Alice A. Danforth, L. A. Danforth, Reading, Mass.; E. T. Harvell and Chas. A. Townsend, Rockland, Mass.; Mrs. E. M. Shedd, Miss Lillian E. Leavitt, Edwin Leavitt, Somerville, Mass.; Mrs. E. A. Martin, Springfield, Mass.; Miss Lucy C. King, Taunton, Mass.; Mrs. George E. Winslow, Waltham, Mass.; Agnes L. Coffin, John R. Coffin, W. Medford, Mass.; Mrs. F. L. Fuller, Clifford D. Winton, Mrs. H. D. Winton, Wellesley Hills, Mass.; J. E. Peirce, Emma F. Vaughan, East Greenwich, R. I.; Mrs. C. E. Peirce, East Providence, R. I.; Mrs. Irving S. Wood, Providence, R. I.; Mrs. W. H. Griffith, Mrs. Willard Kent, W. H. Griffith, Jr., Narragansett Pier, R. I.; J. H. Walsh, East Hartford, Conn.; Mrs. George K. Crandall, New London, Conn.; Mrs. Perry T. W Hale, Middletown, Conn.; Charles Whiting Baker of "Engineering News," Mrs. D. M. Gilbert, Mrs. F. W. Shepperd, Mrs. I. S. Holbrook, Mrs. Louis L. Tribus, Master Lucien Hall Tribus, Mrs. O. B. Mueller, Mrs. Chas. H. White, Edw. S. Cole, Mr. I. S. Holbrook of "Engineering Record," New York City; Mrs. C. E. Davis, Brown's Station, N. Y.; Mrs. Alexander Orr, Gloversville, N. Y.; H. A. Holmes, Waterford, N. Y.; Mrs. F. H. Luce, Woodhaven, N. Y.; Agnes Estes Reimer, East Orange, N. J.; Mrs. J. H. Cook, Mrs. Washington Paulison, Passaic, N. J.; Mr. C. E. Knowles, Mrs. Morris Knowles, Miss Helen Knowles, M. Knowles, Jr., Pittsburg, Pa.; Mrs. Wm. F. Woodburn, Philadelphia, Pa.; Mrs. C. W. Small, Washington, D. C.; R. Winthrop Pratt, engineer Ohio State Board of Health, Columbus, Ohio; Mrs. R. G. Wallace, Mrs. A. B. Mora, R. G. Wallace, Chicago, Ill.; Mrs. George A. Stacy, Marlboro, Mass.; Rev. W. S. Miller, Pittsburg, Pa.; Mrs. J. M. Birmingham, Miss M. E. Dwyer, Hartford, Conn.; Mr. George F. Whitney, "Hudson Contracting Co.," New York City.— 114.

[Names counted twice, — 4.]

Tuesday Evening, September 11.

An informal "smoker" was held in the hotel parlor, to listen to a lecture on the White Mountains, by Prof. George N. Cross, illustrated by stereopticon.

Wednesday, September 12.

The opening session of the convention was held on Wednesday evening, Prof. William T. Sedgwick, President, in the chair.

Mr. Morris Knowles, chief engineer Bureau of Filtration, Pittsburg, Pa., was the first speaker. He gave a "Preliminary Description of the Pittsburg Filtration System," illustrated by stereopticon views. At the close of his address, President Sedgwick said:

"I think we have reason to be proud of this work which is going on in Pittsburg. We are most of us New England men, but we are Americans before we are New Englanders, and it has been a disgrace to our country for a number of years that the rich, powerful, and progressive city of Pittsburg, in the face of repeated warnings, and of universal knowledge of its condition, has gone on furnishing its people sewage-polluted water to drink. If at last it is to have an ample filtration plant, that may be some atonement, although at best it will have been installed too late to satisfy the friends of such as have died of typhoid fever.

"One cannot help being impressed with the tremendous progress which this subject of filtration has made in the past few years. When we think of the Lawrence filter, built in 1893, as the first of any consequence in the United States; when we think how few years have gone by since then, and remember what has been done in Albany and in Louisville and in Washington, and in many other cities and towns in the United States, and now in Pittsburg, we have reason to be very proud of the advances which are going on in water-works sanitation and construction. The time is fast coming when to furnish sewage-polluted water to a community will be regarded as an unpardonable crime, and when any city that continues to do it will be regarded as a city in disgrace.

"No one who has listened to Mr. Knowles can help feeling that here is a plan which has been studied out carefully, in which the possibilities of trouble have been foreseen, as far as any one can foresee them, and which shows an amount of progress which is most promising and interesting. I think we have occasion to rejoice, not only as members of the New England Water Works Association, but as American citizens, that the city of Pittsburg is likely to lose its disgraceful prominence in typhoid-fever statistics. For years every one who has studied typhoid fever in relation to water supplies has pointed out Pittsburg as one of

the worst, if not the worst, among the big cities of the country, and that in the face of wealth, prosperity, and manufacturing intelligence such as the world has perhaps never seen in any other community of the same size. It is incongruous, it is an anachronism, that it should be so, and it is high time that Pittsburg, and all other cities which are now running on similar lines, should reform. That the work happens to be in charge of a member of the New England Water Works Association is to us a double cause for congratulation." [Applause.]

The next paper was by Mr. Carleton E. Davis, department engineer Board of Water Supply, New York City, and was a presentation of "Water Supply Problems on the Isthmus." This was also illustrated by stereopticon views. In presenting Mr. Davis, President Sedgwick said:

"The greatest piece of water-works construction that the world has ever seen, or is likely soon to see, is now in progress on the Isthmus of Panama, — the digging of the transcontinental canal. But although this is the greatest piece of work, there are connected with it many lesser pieces which are perhaps quite as interesting to us as water-works people. All the questions of water supply for the towns and cities on the Isthmus, for the laborers who must work on the canal or who must live there after it is built, are pressing problems which we Americans must meet; and many of them are new problems, because when the Suez Canal was dug engineers hadn't the ideas of the need of pure water that we have to-day, — water of any kind would do to drink then, — but to-day we want to dig our canal in the most honorable and scientific way, and we want the people who are digging it, and the people who are to live there afterwards, to have good water to drink. And here we can again congratulate ourselves, because Mr. Carleton E. Davis, one of our own members, was for a number of months engineer in charge of the water supply and sewerage problems along the line of the canal. He is now department engineer of the water supply of New York City, but he has kindly consented to have made for us some lantern slides illustrating local conditions on the Isthmus, and then to tell us about his own observations and experiences there. He has come to us to-night from New York for this purpose, as Mr. Knowles came

from Pittsburg, and I have great pleasure in presenting him to you at this time." [Applause.]

At the conclusion of Mr. Davis's paper, which was illustrated by a number of interesting lantern slides, the meeting adjourned.

THURSDAY, SEPTEMBER 13, 1906.

The convention was called to order at 10 A.M. by President Sedgwick. The first business was the election of members. The Secretary read the following list of applicants, all of whom had been approved by the Executive Committee:

Resident. — Leon E. Scruton, Rochester, N. H., engaged in engineering and in installing water works; John H. Walsh, Superintendent East Hartford Fire District Water Works, East Hartford, Conn.; George A. Shackford, Water Commissioner, Reading, Mass.; Charles A. Bogardus, Superintendent Chicopee Water Department, Chicopee, Mass.; George H. Shaw, Filtration Engineer Springfield Water Works, Ludlow, Mass.; Freeland Howe, Jr., Norway, Me., Consulting Chemist and Bacteriologist; Henry W. Sanderson, Westfield, Mass., Superintendent Westfield Water Works; Charles A. Townsend, Water Commissioner, Rockland, Mass.

Non-Resident. — H. J. Fuller, Tacoma, Wash., Chief Engineer Tacoma Water Supply, Puget Sound Power Company, etc.; G. R. Coldwell, Brandon, Manitoba, Canada, Chairman Water Works Committee of Brandon.

Associate. — Hudson Contracting Company, cleaning water mains; The Pitometer Company, Chicago.

On motion of Mr. Collins the Secretary was instructed to cast one ballot in favor of the applicants, and, he having done so, they were declared elected members of the association.

The Secretary announced that the Executive Committee unanimously recommended the election of the following-named gentlemen as Honorary Members:

Joseph P. Davis, C. E., Yonkers, N. Y., — formerly City Engineer, Boston, — Chief Engineer of the Sudbury River Water Works, Consulting Engineer Metropolitan Water and Sewerage Board of Massachusetts, etc.

Dr. Henry P. Walcott, Cambridge, Mass., Chairman Massachusetts State Board of Health, member of Metropolitan Water and Sewerage Board of Massachusetts.

Hiram F. Mills, C. E., Lowell, Mass., Chief Engineer of Water Power at Lowell and Lawrence, member State Board of Health of Massachusetts, Consulting Engineer Metropolitan Water and Sewerage Board of Massachusetts.

Frederic P. Stearns, C. E., Boston, — formerly Chief Engineer State Board of Health of Massachusetts, — Chief Engineer Metropolitan Water and Sewerage Board, Consulting Engineer, President American Society of Civil Engineers.

John T. Fanning, Minneapolis, Minn., Consulting Engineer, builder of many water-works systems.

Rudolph Hering, New York City, Consulting Engineer for a great many sewerage and water systems, formerly member of New York Commission on Additional Water Supply.

E. D. Leavitt, Jr., Cambridge, Mass., Consulting Mechanical Engineer, designer of some of the most noted pumping engines ever built.

Edwin Reynolds, Milwaukee, Wis., Consulting Engineer, Allis-Chalmers Company, designer of the Reynolds Corliss engine and of the type of pumping engine built by the E. P. Allis Company and the Allis-Chalmers Company.

On motion of Mr. Charles W. Sherman the gentlemen whose names had been read were unanimously elected honorary members by a rising vote.

On motion of Mr. Sherman the President was requested to appoint a committee of five to nominate officers for the ensuing year. The President later appointed Messrs. Dexter Brackett,* of Boston; George C. Whipple, of New York; A. M. French, of Holyoke, Mass.; Leonard Metcalf, of Boston; and J. C. Hammond, Jr., of Rockville, Conn., as the committee.

The remainder of the morning session was devoted to practical experience papers. In presenting Mr. George A. Stacy, who headed the list of speakers on the program, President Sedgwick said:

"For a long time I have had the feeling that our association was a little bit in danger of getting papers in too large number which were scientific rather than immediately practical; and so I asked the Secretary, in arranging the program for the convention,

* Mr. Brackett having declined to serve on account of ill-health, the President subsequently appointed Mr. George A. Stacy of Marlboro, Mass., in his stead.

to devote one of the best sessions, and if possible the whole of one session, to practical experience papers by members of the association, the idea being that if any member has a particularly interesting or difficult practical problem in which he needs the sympathy and help of his fellow-members, or in connection with which he is entitled to their congratulations for having succeeded in overcoming the difficulty, he should bring it forward so that we may all share in it. The Secretary fell in with the idea cordially, and the regular program for this morning provides for a series of such experience papers. I am sure that this feature will prove of great interest and value to many members of the association.

"It should always be a matter of pride with this association that it brings forward papers of great scientific importance, and thus shows the way for progress in all water-works affairs. I think the association has reason to be proud of the fact that it has had, from time to time, read before it, and published in its JOURNAL, so many papers which have embodied scientific progress. I think in this very convention we are having some of that kind, and I hope we shall have them in all of our meetings; but at the same time we want to remember that this is a practical association and that most of the members of it are interested in the difficult problems of daily administration. I hope the time will never come when we shall fail to recognize that fact, and to give to those men and to those problems due prominence. I am very glad, therefore, that we are to have this morning a number of papers pointing in that direction."

The first paper was by Mr. George A. Stacy, superintendent water works, Marlboro, Mass., his subject being "Trouble with a Check Valve."

The next paper was by Mr. Samuel A. Agnew, superintendent Scituate Water Works, North Scituate, Mass., entitled, "Pumping without Attendance." Mr. Frank L. Fuller, Mr. Daniel N. Tower, Mr. Freeman C. Coffin, and Mr. Wm. H. Thomas also spoke on the use of gasoline, gas, and kerosene engines. Mr. Sherman read a communication from Mr. E. H. Foster relative to pumping without attendance by a centrifugal pump driven by a Pelton motor, the latter receiving its power from the force

main. Mr. A. A. Reimer gave an account of the experience at East Orange, N. J., with a centrifugal pump and electric motor which are in use at a substation there.

The next subject taken up was "Experiences with New England Water Works Association Standard Specifications for Cast-Iron Pipe and Special Castings," and the speakers were Mr. Charles W. Sherman and Mr. A. A. Reimer.

The report of the committee on "Uniformity in the Direction of Opening Hydrants and Gate-Valves and in the Size and Shape of Hydrant and Valve Nuts" was presented by Mr. Frank L. Fuller, chairman. The subject was discussed by Mr. M. F. Collins, Mr. Freeman C. Coffin, Mr. Alex. Orr, Mr. George A. Stacy, and Mr. Charles W. Sherman and Mr. Edmund M. Blake. The report was accepted as a report of progress, and the committee was requested to continue its work and report finally at some meeting during the winter.

At the evening session two papers, each illustrated by stereopticon views, were read. The first, by Mr. H. W. Spooner, engineer Water Department, Gloucester, Mass., was a description of the "Construction of a Subaqueous Tunnel at Gloucester"; and the second, by Mr. George H. Snell, water commissioner and superintendent water works, Attleborough, Mass., a description of "The New Reinforced Concrete Standpipe at Attleborough." Mr. Frank A. Barbour, of Boston, and Mr. L. C. Wason, president of the Aberthaw Construction Company, Boston, also spoke concerning the Attleborough standpipe.

Friday, September 14, 1906.

The convention met for its final session on Friday evening.

President Sedgwick read a paper, submitted by Mr. F. F. Forbes, superintendent water works, Brookline, Mass., entitled "Experiences in Introducing Compulsory Meterage, and Results Obtained by Metering All Supplies in the Town of Brookline, Mass."

The Committee on Meter Rates, through its chairman, Mr. Freeman C. Coffin, presented a progress report.

Mr. Joseph E. Beals, superintendent water works, Middleboro, Mass., read an experience paper entitled, "Homespun Device for Raising Pipe in the Trench."

Prof. Adolph Black, of Columbia University, New York, was elected a non-resident member.

A paper by Mr. George C. Whipple, New York City, on "The Cleveland Typhoid Fever Epidemic of 1903–4," was read by title, the discussions, if any, to be printed after the publication of the paper in the JOURNAL.

The President read the following letter, and announced that the editor would see that such portions of the various proceedings of the association as are available would be forwarded to Mr. Simin:

N. P. SIMIN, C. E.,
President of the Permanent Bureau of Russian Water Works Association.
RUSSIA, MOSCOW, Razgulay, 3.

The 12–25 June, 1906.

MR. WILLIAM T. SEDGWICK, President of the New England Water Works Association, Boston, Mass.

Dear Sir, — Since 1893 we have had seven meetings of the Russian Water Works Association; their proceedings are printed in seven volumes. Moreover, our congresses have worked out a standard for cast-iron pipes and connection details, which are set forth in tables and drawings.

I address myself to you with a proposal to exchange publications and reports of the American and Russian associations.

At the same time I am addressing a similar proposal to the German, English and French associations, and I hope that my proposal of a relation of national associations will be welcomed.

If you consent to it, please give me an answer; I will then send all the printed matter of the Russian Association to the headquarters of the New England Association.

Yours very truly,

N. P. SIMIN,
President of the Permanent Bureau.

T. HALTURINE, *Secretary.*

The President announced that an invitation had been received to hold the next annual convention of the association at Norfolk, Va.

After calling Vice-President John C. Chase to the chair, President Sedgwick then spoke on the "Protection of Water Supplies from Pollution during the Construction, Maintenance, and Operation of Railroads; with Special Reference to the Water Supply of Seattle, Wash."

Mr. H. L. Weston, Committee on Exhibits, presented the following report.

REPORT OF COMMITTEE ON EXHIBITS.

As chairman of the Committee on Exhibits at the New England Water Works Association Convention at Fabyans, I desire to report that the following associate members made exhibits at the convention.

Ambursen Hydraulic Construction Company . .	Concrete dams.
Anderson Coupling Company	Brass goods.
Ashton Valve Company	Valves and gages.
Coffin Valve Company	Valves and hydrants.
Fairbanks Company	Gates and hydrants.
Garlock Packing Company	Packings.
Hart Packing Company	Packings.
Hersey Mfg. Company	Meters.
Jenkins Brothers	Valves and packings.
Lead Lined Iron Pipe Company	Lead lined pipe.
H. Mueller Mfg. Company	Brass goods.
National Meter Company	Meters.
Neptune Meter Company	Meters.
Pitometer Company	Pitometers.
Pittsburg Meter Company	Meters.
A. P. Smith Mfg. Company	Tapping machines, brass goods, etc.
Thomson Meter Company	Meters.
Union Water Meter Company	Meters.
R. D. Wood & Company	Valves, hydrants, and pipe.
Henry R. Worthington	Meters.

The number of exhibitors was not so large as at previous conventions nor the exhibits so extensive, notwithstanding the fact that some little effort was made to secure a good exhibition. This was probably owing to the fact that the convention as a whole was taken prëminently as a pleasure outing and the prevailing idea among the associate members seemed to be that exhibits were of minor importance.

Yours very truly,

H. L. WESTON.

Adjourned.

EXECUTIVE COMMITTEE.

On Steamer "Philadelphia,"
Boston Harbor, June 13, 1906.

Present: Vice-President Joseph M. Birmingham and Frank E. Merrill, Charles W. Sherman, Robert J. Thomas, L. M. Bancroft, and Willard Kent.

Mr. Merrill, member of committee on June meeting and September convention of the association, reported for the committee their action in relation thereto, recommending that the next annual convention be held at the White Mountains; whereupon it was

Voted: That the annual convention of the association be held at the White Mountains, September 12, 13, and 14, 1906.

After discussion of the question of transportation and hotel accommodations, it was

Voted: That Mr. Merrill be, and hereby is, empowered to make all necessary arrangements therefor and to act as transportation agent and conductor of the excursion in his own behalf.

Eight applications were received and recommended for membership, viz.:

Non-Resident Active: George Morgan Bacon, Salt Lake City, Utah; S. J. Rosamond, Fort Smith, Ark.; Robert J. Harding, Hudson, N. Y.; Charles L. Fox, Pittsburg, Pa.; A. W. Shaw, Brandon, Manitoba, Canada.

Resident Active: Gardner T. Swarts, M.D., Providence, R. I.; Charles E. Childs, Somerville, Mass.; E. C. Crosby, Brattleboro, Vt.

Adjourned.

Willard Kent, *Secretary.*

Tremont Temple, Boston, Mass., August 24, 1906.

Meeting of the Executive Committee of the New England Water Works Association.

Present: F. W. Gow, L. M. Bancroft, George A. Stacy, C. W. Sherman, Willard Kent, F. E. Merrill, John C. Chase. Vice-President Gow presided.

Voted: That the Committee on Convention be authorized to

provide suitable entertainment for the ladies on one day of the convention, at the expense of the association.

Voted: That sessions of the association be held on mornings of Wednesday and Thursday, and on evenings of each day of the convention, the morning sessions to be subject to adjournment according to weather conditions.

Voted: That a "smoker" be held on the evening of arrival, Tuesday, September 11.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

FABYAN HOUSE,
FABYANS, N. H., September 12, 1906.

Present: President William T. Sedgwick and George A. Stacy, John C. Chase, Charles W. Sherman, James L. Tighe, Frederick W. Gow, Robert J. Thomas, Willard Kent, Lewis M. Bancroft, and Frank E. Merrill.

Thirteen applications were received and recommended for membership, viz.:

For Active Membership: G. R. Coldwell, Chairman of Committee Municipal Water Works System, Brandon, Manitoba, Canada; H. J. Fuller, Chief Engineer Tacoma Water Supply, Tacoma, Wash.; Charles A. Townsend, Water Commissioner, Rockland, Mass.; Henry William Sanderson, Superintendent Westfield Water Works, Westfield, Mass.; Freeland Howe, Jr., Chemist and Bacteriologist, Norway, Me.; George H. Shaw, Filtration Engineer Springfield Water Works, Ludlow, Mass.; Charles A. Bogardus, Superintendent Chicopee Water Department, Chicopee, Mass.; George A. Shackford, Water Commissioner, Reading, Mass.; John H. Walsh, Superintendent East Hartford Fire District Water Works, East Hartford, Conn.; Leon E. Scruton, Water Works Engineer, Rochester, N. H.; Adolph Black, Professor of Civil and Sanitary Engineering, Columbia University, N. Y.

For Associate Membership: The Pitometer Company, 310 Ashland Block, Chicago, Ill.; Hudson Contracting Company, engaged in cleaning water mains, 27 William St., New York City.

The following names were recommended for honorary membership:

Joseph P. Davis, Dr. Henry P. Walcott, Hiram F. Mills, Frederic

P. Stearns, John T. Fanning, Rudolph Hering, E. D. Leavitt, Jr., Edwin Reynolds.

The subject of annual convention for 1907 was discussed. An invitation from Norfolk, Va., was read; its acceptance, for various reasons, was not deemed advisable.

Washington, D. C., was suggested, and, on motion of Mr. Stacy, the subject was referred to the next meeting of the Executive Committee.

No further business appearing, meeting was adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

William W. Burnham died of typhoid fever, in Wilmington, N. C., on August 10, 1906.

Mr. Burnham was thirty-one years of age. He went from Biddeford, Me., in 1905, to act as engineer for the Carolina Trucking and Development Company, at Wilmington. He leaves a wife.

He was elected a member of the New England Water Works Association on September 13, 1905.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XX. December, 1906. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

PUMPING WITHOUT AN AIR CHAMBER.

BY GEORGE A. STACY, SUPERINTENDENT WATER WORKS, MARLBORO, MASS.

ERRATA.

On page 352 of the JOURNAL for September, 1906, nine lines from bottom of page, for "Fort Fairfield" read "Fryeburg."

On the same page (352), seven lines from bottom, for "an adjoining town," read "Portland, about 50 miles distant."

the pump was working through 1 500 feet of force main directly up to the reservoir, and I did not know but it was possible that we could remove the air chamber and never notice the difference.

I had no occasion to try the experiment, however, until a few months ago, when word came from the pumping station that when they shut down and released the water from the pumps, through what we call the starting valve, the pressure was not reduced, and the water kept coming as evidence that there was something the matter with the check in the force main. On investigation, I found that one of the valves had broken. It was a three-ported

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BY GEORGE A. STACY, SUPERINTENDENT WATER WORKS, MARLBORO, MASS.

[*Presented September 13, 1906.*]

Some few years ago I was standing in our pumping station near a compound duplex condensing pumping engine of about three million capacity, with a friend of mine, who had had large experience in the designing and the management of pumping engines. Noticing the generous proportions of the air chamber on this particular pump, he made the remark that he believed that under the conditions under which that engine was working, the air chamber was not necessary, and was, in fact, practically worthless as regards any efficiency or smoothness of working of the pump. I paid no particular attention to it at the time, although it struck me as possible that it might be so, as we had begun at that time to do away with air chambers on boiler feed pumps, the boiler itself acting as the air chamber. In this case the pump was working through 1,500 feet of force main directly up to the reservoir, and I did not know but it was possible that we could remove the air chamber and never notice the difference.

I had no occasion to try the experiment, however, until a few months ago, when word came from the pumping station that when they shut down and released the water from the pumps, through what we call the starting valve, the pressure was not reduced, and the water kept coming as evidence that there was something the matter with the check in the force main. On investigation, I found that one of the valves had broken. It was a three-ported

valve, built about twenty-three years ago, and the closing mechanism of the valves or ports was made of leather, — a type which you are probably all familiar with. To-day check valves of small size are sometimes made that same way. That is, the leather constitutes the covering for the valve-seat, being riveted to plates of iron to give stiffness, the joint or hinge being made by the leather between the plates; one which covers the opening and the other which is bolted to the body of the valve. The continual working of the valve for years weakening the leather, the one covering the middle port broke and dropped down. Not having leather I considered suitable to renew it with, we put the bonnet on the valve until such time as we could get it from the manufacturer of the valve, and went ahead with the pump without the check. Of course, the first day we had the air chamber charged as much as usual. In starting up the next morning, I told the engineer to go ahead with the pump all charged and the pressure on it, and if it didn't start up all right, to send for me. I will say, by the way, that I am responsible for the pumping engines on our works and all the mechanical details, and when anything goes wrong, I am supposed to be the doctor. The pump started all right with a full reservoir head on it, but in the afternoon of the second day I was called up and told that the pump wasn't working first rate. I went up to the pumping station and I found that at the end of the stroke there was a considerable jar. The pump had always worked very smoothly; as we say, it turned the corners quietly, but now you could see a marked change in the running. It was nothing very injurious, but it was rather annoying to an engineer; the noise was like discord to a musician. You would notice, as soon as you came within hearing of the pump, that there was something a little out of the usual, but, as I say, it was nothing dangerous, only it was unpleasant.

The next morning I went up to see if everything was running properly. The pump had started up all right again, but there was still this hammer at the end of the stroke. Across the street from the pumping station are one or two houses, and the principal of one of our schools lives in one of them. His wife came over and said she wished I would come over to the house and see if I could tell her what was the matter with the water pipe. She said

she had had a plumber there the afternoon before, and about the time he went away the noise stopped, but that morning it was as bad as ever, so she was afraid perhaps he didn't understand his business and she wanted me to come over. I went over and the sound that I heard was what is familiar to most of us when the ball cock in a tank gets to vibrating, as it will sometimes under certain conditions, and we get that chug, chug, chug, all over the house. Of course when that is kept up incessantly all day long it would be rather annoying to a lady, or even to a man with strong nerves.

In my great wisdom I said at once, "Oh, I will fix that for you very quickly." I went to the water-closet tank, but I found everything quiet there, no vibration whatever. I asked where the tank for the hot water was, and she told me it was up in the attic, so we got a ladder and I crawled up through the scuttle-hole and brushed away the cobwebs and thought surely I would locate the trouble there, but to my surprise I could find nothing, and still this noise was going on. I thought less of my own wisdom at that time than I did when I started in. On coming down stairs I said, "How long has this been going on?" She replied, "It commenced yesterday, and I sent for the plumber and he came and worked all the afternoon and about the time he was going away the noise stopped, and he said he guessed it would be all right." I asked what time he went away, and she said about five o'clock. (That was about the time we stopped the pump.) I said, "Did it do this all night?" She said, "No; we didn't hear anything until this morning, when it commenced again. When we open the faucet we don't hear it." I went and opened the faucet and let a stream run about as big as my little finger, and the noise ceased; but when I closed the tap again, it would start up as before. I looked all around to see if I could find anything in the plumbing which would lead me to suspect a cause for that. Of course it flashed into my mind that the pulsations of our pump, in the absence of the air chamber, had given a new action to the water in the force main that it hadn't possessed before; but why it should set up a vibration in the service pipe to this house and not affect the service pipe to the next house, I didn't know. The service was metered, and the lady rather

objected to letting the water run, but I wanted a little time to consider the matter, and I said, "You let the water run a little, and I will make it all right on the meter question, and if it continues to make a noise, let the water run more, and I think we will solve the trouble to-morrow, and you won't have any more difficulty."

On my way to the engine house I was thinking how I was going to remedy the trouble. It was simple enough. All we had to do was to shut the main gate on the force main, using the starting valve to discharge the water and relieve the pressure from the pump, and then in the morning use the charging valves to charge the pump the same as usual, and after getting the pressure equalized, gradually open the valve on the main and go ahead. We then had air enough in the air chamber to run part of two days before the water absorbed the air.

It came to me that an air chamber even under those conditions was of some use, and that if a man was offering me an engine and saying he would guarantee it to work all right without an air chamber, I should take exception to it.

We never had any trouble after that, but it is a mystery in my mind yet what caused the water hammer in that particular service and not in the adjoining one, when the services were exactly alike, except that this one was perhaps sixty feet longer. This incident brought to my mind that while theory is an excellent thing, practical experience is oftentimes a good deal better. And while this was not destructive, and wouldn't have prevented the continued action of the pump, it did prove to me that an air chamber is worth all it costs in preventing such conditions, even if they were not half as severe as these were.

This may seem to be a very simple matter, but it impressed itself on my mind as one of the little things which go to make up our life and bother us a good deal sometimes, and if we have the problem already solved, we haven't got to go and hunt up the solution of it.

DISCUSSION.

A MEMBER. What kind of a pump was that?

MR. STACY. A Blake, just like all the tandem compound duplex condensing pumping engines, built about twenty-three years ago, of the old Worthington type.

Mr. Frank L. Fuller. I didn't exactly understand, Mr. Stacy, whether the air had been exhausted from the air chamber and after it was replaced there was no further trouble.

Mr. Stacy. I think very likely I didn't make myself plain on that point. On working the pump for the first day, you could see the water gradually creep up in the glass until the air was out of sight. Of course there was still some left, but the time came when the water absorbed all the air there was in the chamber, and we got a solid column of water, when, of course, the action of the air chamber was nothing, and at that time came the hard action on the pump and the water hammer in the house.

Mr. Fuller. I have had that same trouble in my own house at Wellesley. I think my house must be nearly two miles from the pumping station, and what seems rather to conflict with Mr. Stacy's statement or theory is that we have had that trouble early in the morning before the pump would be started. I have generally, by opening a faucet at the end of a long pipe in the cellar, cured the trouble for a while, and then perhaps in a month or two we would have it again. I had rather concluded it was due to an accumulation of air in the pipes in the house, but I never was certain of that, because on opening the faucet I never noticed any especial discharge of air. That word "chug" expresses it exactly.

Mr. Stacy. In relation to that, Mr. President, there is another little experience I had in this way. A man I have been acquainted with for many years said to me, "George, you say that a meter can't run unless water goes through it?" "Well," I said, "water or air or something of that kind; it doesn't run of its own volition." He owned considerable real estate and had a number of meters, and he said, "I have a meter which runs when there isn't any water or anything else running through it." I said, "I can't see that meter any too soon." So he said, "I will drive you up soon." It was just on the outskirts of the city, perhaps half a mile from city hall. I said, "Don't forget, because that is the biggest wonder I know of." He says, "I know what you believe, but that is the fact, and I will show it to you." I said, "All right." So it went along, and every afternoon or every time I met him I said, "I want to see that

meter, but I don't want to go without you; I wouldn't miss seeing that meter for anything." He couldn't go then and it went for almost a week, when he met me and said, "George you needn't go." I said, "Why?" "Well," he says, "I have discovered what the trouble was. You said that no meter would run if we wa'n't drawing water, but we wa'n't drawing water at that place." The fact was that there was a long pipe which led out to the stable; the meter was in the basement of the hotel, and after shutting the faucet in the stable one day, he went and looked at his meter, and he saw the hand moving and it kept moving a little bit for some time. He rushed upstairs and couldn't find anybody drawing water, and he came back and the hand was still moving, and at last somebody opened and closed a faucet and it then stopped. He went and tried it again and it did the same thing, so he thought he had one of those wonderful things, a meter running with no water passing through it. The explanation was that way up in the attic, out of sight and hearing, except for what noise came through the piping system, there was a tank which supplied the hot-water system, with the usual ball cock attached, and the pipe running to the barn was long enough so that the water hammer on closing the faucet would counterbalance the ball on the lever; this water hammer and the reaction would cause the ball to vibrate, and a small amount of water would escape at each vibration, which was recorded by the meter. As he knew that nobody was drawing water in the house, he was thoroughly convinced he had found a meter which was actually going without any water passing through it. I only wish I had gone up there myself before he discovered it, and then I would have had the glory of solving the mystery.

THE NEW WATER SUPPLY OF THE CITY OF BROCKTON.

BY CHARLES R. FELTON, CITY ENGINEER, BROCKTON, MASS.

[*Read November 14, 1906.*]

Brockton is a city of about 50 000 inhabitants, chiefly engaged in the manufacture of shoes. Prior to 1903, water was taken from an artificial reservoir having an area of about ninety acres and a watershed of 3¼ square miles, and situated in the town of Avon. This water, while not unhealthful, was very highly colored, in some years averaging over .80, and in the lowest year never running below .48. The poor quality of the water, however, was not the primary cause for seeking a new supply.

The lowering of the reservoir to a depth of about seven feet below the rollway during the year 1899 led to the serious consideration of a new water supply, which had already received attention from Mr. F. Herbert Snow, formerly city engineer, and Mr. Horace Kingman, the superintendent of water works, who had made an excellent report. As the estimated quantity procurable from this source in a dry year was only 1 500 000 gallons per day, and our present average use of water is nearly 2 000 000 gallons, it is obvious that we moved none too quickly in the matter.

At this time the writer was asked to report all possible sources of supply to some expert to be selected by himself, and accordingly all available information was submitted to Mr. Desmond FitzGerald, of this society, and out of a large number of more or less desirable projects he reported most unqualifiedly in favor of Silver Lake. Even after this opinion was rendered, it was over a year before we were able to get the money appropriated to start on the work, the interim having been used in the discussion of the various schemes by the city government, where, curiously enough, a man's judgment on the question of water supply seemed to be quite

largely influenced by his party affiliations, — almost all the Republicans seeming to believe that Silver Lake was the best place to go, and the Democrats seeming equally unanimous in the opinion that while there might be several other reliable sources, Silver Lake was certainly out of the question. Having finally completed the work, however, every one, even its bitterest opponents, seems to be well pleased, and at least two of them now point proudly to their names on the bronze tablet at the pumping station commemorating their achievements as members of the City Council.

The selection of this source, however, on account of its limited watershed, was to a certain extent dependent on the amount of water which was deemed requisite for a future supply, and to justify my somewhat radical conclusions as to the proper amount of water for a city to use, I am giving the following table, showing the consumption of water in Brockton for the last fourteen years.

TABLE No. 1. WATER CONSUMPTION IN BROCKTON SINCE 1892.

Water mains in 1892 = 43.74 miles; in 1905 = 97.366 miles.

Year	Population.	Total Consumption (million gals.).	Daily Consumption in gals. per capita.	Domestic use in gals. per capita. Metered.	Unmetered.	Manufacturing (gals. per capita).	Street Sprinkling (gals. per capita).	Fountains (gals. per capita).	Unaccounted for (gals. per capita).*
1892	29 643	271.6	25.0						
1893	30 817	264.1	23.5						
1894	31 993	323.2	27.7	6.7	3.8				
1895	33 165	399.6	33.0	7.3	3.2	2.4	1.8	1.5	16.8
1896	34 544	403.8	32.0	9.2	3.3	3.2	2.2	1.4	12.7
1897	35 923	386.1	29.5	8.5	2.6	4.0	2.8	1.4	10.2
1898	37 302	369.3	27.1	10.3	2.8	2.7	2.2	1.3	7.8
1899	38 681	414.7	29.4	11.0	2.7	3.6	2.6	1.3	8.2
1900	40 063	429.0	29.3	10.9	2.5	4.0	2.5	1.3	8.1
1901	41 610	447.5	29.1	11.5	2.1	4.0	2.4	1.4	8.0
1902	43 159	506.8	32.2	12.8	1.4	4.2	2.2	1.6	10.0
1903	44 704	537.8	33.0	13.5	1.4	4.9	2.1	1.6	9.5
1904	46 248	591.3	35.0	13.4	1.5	4.8	2.1	1.5	11.6
1905	47 792	621.4	35.6	15.3	1.6	5.1	2.3	1.7†	9.6

* Includes all use for flushing water and sewer pipes, fires, and slip of pumps.
† 16 fountains.

The somewhat rapid increase during the past year or two has been partially accounted for, and the consumption is now below 35 gallons per capita.

The rate of consumption per capita which it was assumed in 1901 would be used was as follows:

1905	35 gallons.
1910	37 „
1915	39 „
1920	41 „
1925	43 „
1930	45 „

or, in other words, it was assumed that we should never use over 45 gallons per capita.

While it may seem to many of you who have large per capita consumptions improbable that we shall be able to keep our consumption down to these figures, I would say that for the last five years we have been able at the *beginning* of the year to predict our consumption usually within one per cent. of the actual use, and always within five per cent. This, however, may have been and probably was due as much to good luck as good judgment. A monthly estimate of the water consumption for the year is made by the city engineer, based on the probable increase in population and legitimate use, and handed to the superintendent of water works; and any increase over this prediction is never considered as a legitimate increase in the consumption unless borne out by the meters or other reasonable cause, and an explanation is immediately sought by the superintendent, who last year found a leak amounting to over 200 000 gallons per day by examining the pipes under the bridges.

It is noteworthy that we have only one period of high consumption, namely, in the summer, whereas unmetered supplies commonly have a high period during the winter months.

The ratio of each month to the average monthly consumption as now used in these estimates is as follows:

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
.95	.90	.91	.87	1.08	1.12	1.18	1.13	1.05	.98	.88	.95

In view of our past experience, we did not figure on the necessity for such a large consumption of water as is usually considered advisable, believing that the provision of such extended works as would be required to furnish these large amounts of water would be unwise and unwarranted in our particular case.

Silver Lake is distant from Brockton City Hall, in a straight line, 11½ miles, and is situated in four different towns, viz., Halifax, Pembroke, Plympton, and Kingston. It is 644 acres in area, and has a maximum depth of 72 feet; its elevation above city base is 50 feet, and its total watershed, including water surface, is 4.4 square miles. Its shores are sandy, and soundings show no mud of any consequence within 25 feet of the surface. The total population on the watershed in 1897 was 50, or 18 to the square mile.

The area and storage capacity of the lake for each successive five feet is as follows:

Depth.	Area.	Storage Capacity in Million Gallons.
At high water	644 acres.	
		5 371
5 feet below high water	538 "	
		4 370
10 " " " "	414 "	
		3 563
15 " " " "	372 "	
		2 902
20 " " " "	337 "	
		2 312
25 " " " "	286 "	
		1 804
30 " " " "	238 "	
		1 353
40 " " " "	120 "	
		606
50 " " " "	64 "	
		198
60 " " " "	21 "	
		37
70 " " " "	2 "	

On account of its immense storage capacity, in proportion to its watershed, it is obvious that the date at which we reach the

amount of consumption which the watershed would supply continuously is not the date nor the consumption which the lake is capable of supplying, in figuring the date when more water will

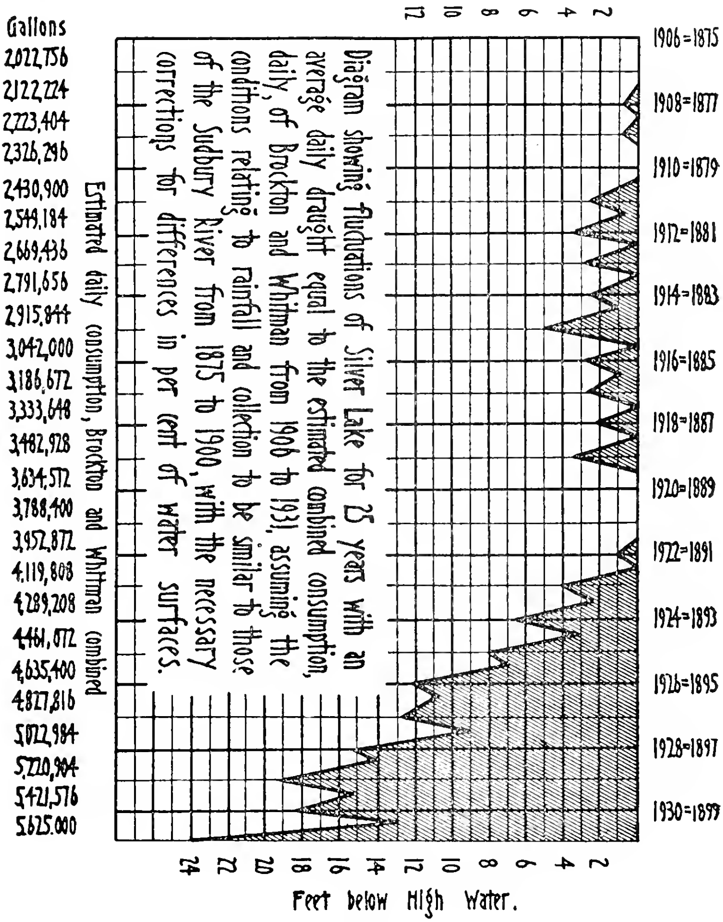


FIG. 1.

be required. Assuming that the next quarter of a century will have the same rainfall as the twenty-five years just passed, and basing our collection on the Sudbury River records, the above

diagram, Fig. 1, shows that the lake would furnish us until the combined consumption of Brockton and Whitman is over 5 000 000 gallons per day, without drawing the water down over 16 feet, or till about 1930. The length of this period warrants the assumption that the next similar one will not be materially different, although the sequence of dry seasons may be materially changed. It will be noted in this particular case that if it were to be assumed that a watershed were good only till that time at which it ceased to fill every year, the limit of capacity would be reached in six years, while under our estimated probable conditions of increase we could go eighteen years without ever drawing the water down to a point where it would not rise within *two feet* of high water every year.

While it is estimated that the lake will furnish a supply for nearly twenty years, and never fail to fill to within two feet, or until the daily consumption is about 4 200 000 gallons, which is the amount that this storage would supply continuously, it would necessitate the drawing down of the water nearly 20 feet, and under the assumed conditions there would be many years when the lake would not fill. A draught of 3 500 000 gallons per day under the above assumptions would result as shown by the following diagram, Fig. 2, and during the predicted dry spell it would perhaps be best to use some water from the old supply, to make sure of the lake filling. While it might be somewhat optimistic to figure that this would occur exactly as figured, provided no other supply were at hand, with our old supply always ready we feel that we can risk our assumptions being practically realized.

While the water of the lake is practically colorless and tasteless at most times, we have a short period of about three weeks when there is taste and odor although no high color.

For the past six months, regular weekly, and at times semi-weekly, chemical analyses and microscopical examinations of the Silver Lake water and of the several inlets to the lake have been made by Mr. George E. Bolling, our chemist and bacteriologist, and the following data are supplied by him.

The data afforded by the chemical analyses have indicated an absolute freedom from pollution from any animal sources.

The microscopical examinations have shown the presence of 33 genera at one time or other during the six months the water

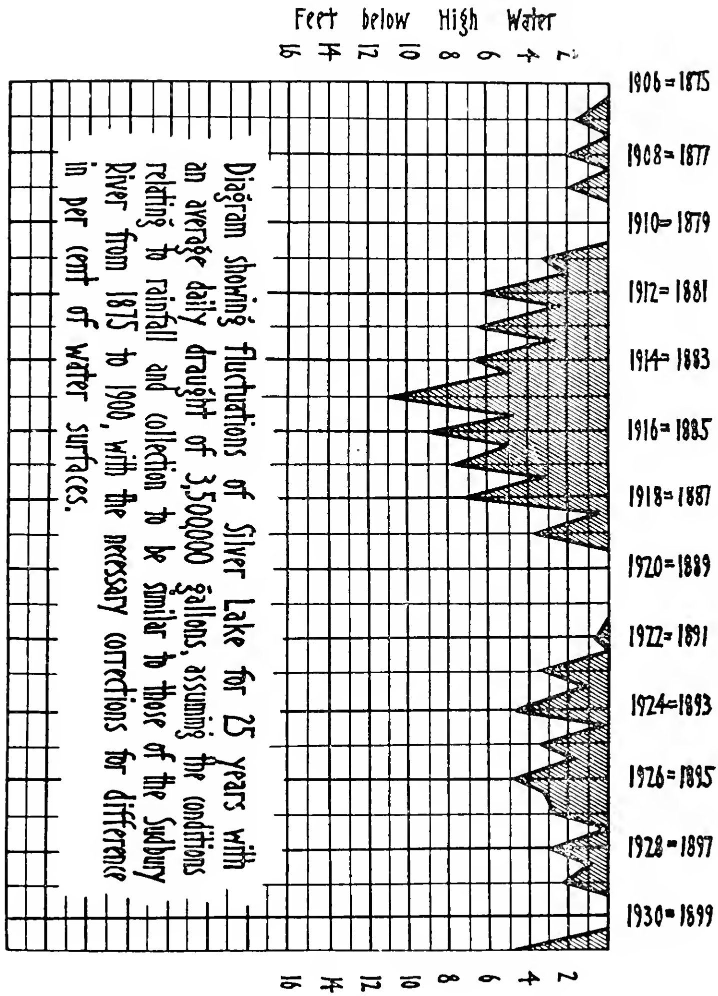


FIG. 2.

has been examined. Of these 33 genera, 18 were plants and 15 animals. Melosira has been by far the most abundant, reaching the number of 2 070 standard units per cubic centimeter on March

20, 1906. From this number it decreased steadily until June, when the organism was present to the number of 30 to 40 standard units per cubic centimeter. This diatom has invariably been present in all the samples taken from the lake, varying from 5 to 2 070 standard units per cubic centimeter. At the time of its greatest abundance, the turbidity of the water was reported as "slight" and the odor "faintly vegetable" in the cold and "vegetable" in the hot odor determinations, while the various data of the chemical analyses showed no change from the ordinary. No complaints whatever were received from consumers at this time.

The organism known as anabena appeared at the intake on July 10, to the amount of 139 standard units per cubic centimeter, having been detected in very small numbers in another part of the lake a few days previously. It had increased to 159 standard units per cubic centimeter by July 23, and then decreased to 17 standard units by August 1, and on August 6 none were found. Numerous complaints were received from consumers during this period, the process of disintegration undergone by the fragile organisms while subjected to pressure in the force main serving to liberate the odor peculiar to this species of algæ, so that it was readily appreciable in water drawn from the cold-water faucets, and greatly intensified and much more unpleasant from the hot-water faucets.

The first experience Brockton had with this troublesome plant was in 1905, during the first summer the new supply was used. At that time some of the dwellers near the lake asserted that the growth occurred only once in about every six or eight years, but its recurrence this summer would seem to indicate the probability of an annual visitation from the organism. At the time of its greatest abundance the odors reported on the samples taken from the lake were "faintly vegetable" in the cold and "distinctly vegetable, corn-silk" in the hot odor determination, but as has been indicated before, these odors were intensified during the passage of the water through the pipe system to the consumer.

Crustacea have invariably been present in small numbers in all of the samples examined.

Following is a table showing the average analyses of the water of Silver Lake for the past three years:

PARTS IN 100,000.

Year	Color.	Residue on Evaporation: Total.	Residue on Evaporation: Loss on Ignition.	Residue on Evaporation: Fixed.	Ammonia: Free.	Ammonia: Albuminoid: Total.	Ammonia: Albuminoid: In Solution.	Ammonia: Albuminoid: In Suspension.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
1903...	.09	2.96	1.10	1.86	.0016	.0138	.0113	.0025	.60	.0007	.0000	.25	0.4
1904...	.10	3.01	1.30	1.73	.0013	.0143	.0123	.0020	.62	.0010	.0000	.27	0.6
1905...	.10	3.18	1.26	1.92	.0020	.0120	.0099	.0021	.61	.0019	.0000	.22	0.6

THE FORCE MAIN.

The great length of the force main, and a difference of about $100 000 in the cost between the various trade sizes of iron pipe at about the probable limits of reason, viz., 20-inch, 24-inch, or 30-inch pipe, involved some very interesting work which space will hardly allow me to enter upon, as the various elements affecting the choice of a size would make a paper of reasonable length in themselves. Suffice it to say that for the 11½ miles of force main a 24-inch pipe was selected, rather than a 20-inch or a 30-inch, and fulfilled the conditions nearly enough to render it unnecessary to attempt a special size between the usual trade sizes.

As a rule in the streets the top of the pipe was laid about 4 feet below the surface; over private land about 3½ feet was usually sought, although we have some stretches of considerable length where the pipe is not covered over 18 inches. One course which we adopted, although not usually followed in pipe laying, was the filling of the joints inside of the pipe with Portland cement. My chief object in doing this was to reduce friction by adding to the interior smoothness. I figured that a reduction of 3 feet in the friction head would pay for the cost of doing the work. A careful friction test of the pipe since that time does not show conclusively that the friction was materially reduced, as it was almost exactly what is given in Weston's well-known tables for new pipe. This pipe was from one to three years old, however, at the time of the

test, but other friction tables give much lower friction rates than Weston's.

In the trench with the force main was laid a 6-wire lead cable for the telephone service and the Winslow recording apparatus. This cable was placed in a $1\frac{1}{2}$-inch wrought-iron pipe, largely old pipe secured from the junk man.

FIG. 3.
Scale of Plan, about 5 miles to an inch.

Air valves were placed on the main at all the summits, there being 22 on the line. We decided not to put in automatic air valves, but to send over the line occasionally and open them up. They consist simply of a regular $1\frac{1}{4}$-inch corporation and open-way valve, with a pipe running up nearly to the surface of

FIG. 1. FOUNDATION, SILVER LAKE PUMPING STATION.

FIG. 2. SILVER LAKE PUMPING STATION.

the ground and a gate box over the pipe. A recent opening of all the valves after three months' operation showed no air in any summit except the one nearest the pump, where there was a very considerable amount, taking about one and one-half minutes to expel it before we got any water.

It may be interesting to state that the pump has been in operation over a year, under a pressure as high as 160 pounds, and that it has been necessary to remove only one cracked pipe; no joint leaks have yet been discovered, one joint leak having been recalked before the pump was started.

LEAKAGE IN THE FORCE MAIN.

There being but very little published information on the actual leakage in water pipes, it was decided to test this leakage in the force main.

As the pipe was laid from Brockton towards Silver Lake, it was possible to turn the water in as soon as the work was completed. A by-pass of 1-inch pipe with a $\frac{5}{8}$-inch disk meter was placed on the 24-inch main at a 24-inch gate, and the gate was closed here and at the end of the construction. The total distance was 22 476 feet, and the following observations were taken: From August 31 at 2.15 P.M. to September 1 at 7 A.M., about nine hours, the leakage was at the rate of 285 gallons per day; from September 1 at 7 A.M. to September 13 at 12 M., about twelve days, the leakage was at the rate of 277 gallons per day; the latter being at the rate of 65 gallons per day per mile of 24-inch pipe under an average pressure of 68 pounds. There had then been added 3 334 feet of pipe, making the total length 25 810 feet. The gate was opened and the following results were observed:

Average for first	$2\frac{1}{4}$ days,	the meter showed	100	gal. per day per mile.
" " next succeeding	$1\frac{3}{4}$ days,	"	82	" " " " "
" " " "	4 "	"	58	" " " " "
" " " "	13 "	"	32	" " " " "
" " " "	50 "	"	20	" " " " "

The noticeable decrease may have been due to the stopping up of minute leaks, or possibly to the compression or expulsion of air in the summits.

After this it became inconvenient to make further tests; but desiring to get a test on the whole line, 61 000 feet in length, in combination with a friction test, after the pumps had been running about a year, all gates leading from the main were closed and observations were taken of the lowering of the water in the standpipe. This necessitated closing about 50 services, and about 50 other gates, comprising sizes 6-inch, 8-inch, 12-inch, 16-inch, and 24-inch, with one house service open. This indicated a leakage of 285 gallons per day per mile, under an average pressure of 71 pounds. While this does not show conclusively that the leakage in the force main was not less than 285 gallons per day per mile, it shows that it was not more than that.

A pipe wagon, designed by the superintendent, Mr. Kingman, is shown in the accompanying photograph. This apparatus is very quickly loaded and unloaded, and allows a pipe to be conveniently dropped at any point.

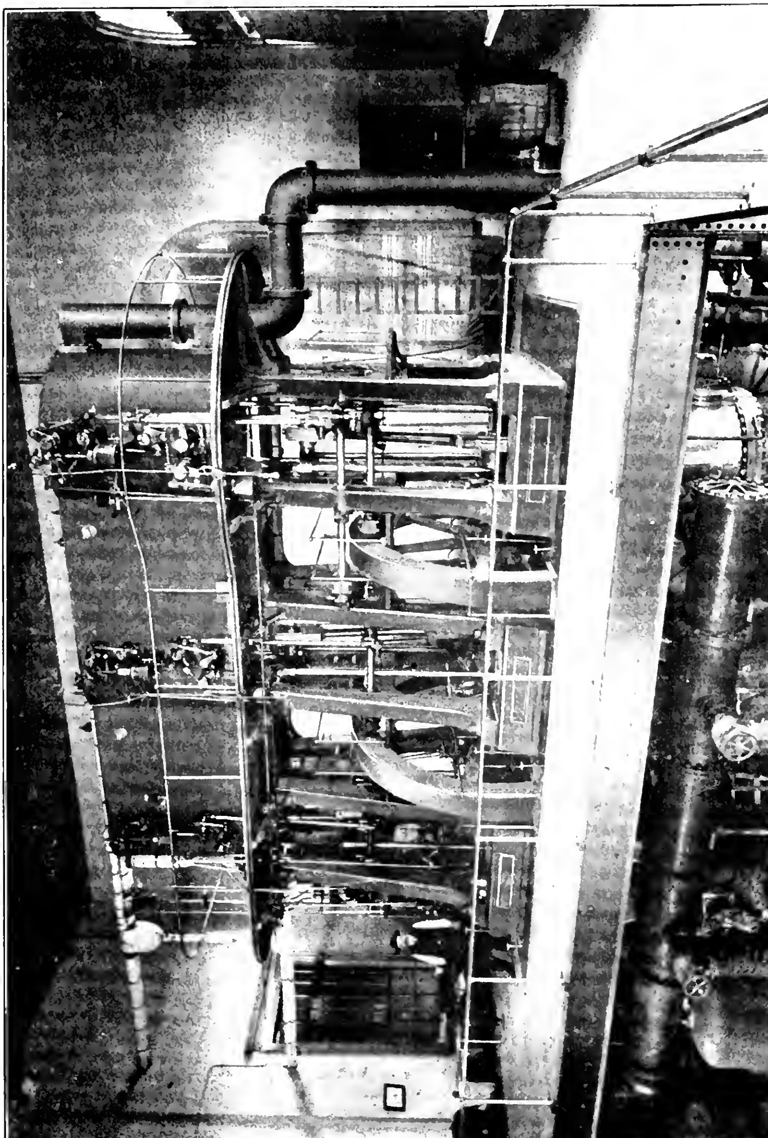
PUMPING ENGINE ECONOMY.

In the selection of the necessary duty to be specified for the pump, the following table was used, it being an adaptation of a table published by Mr. Coggeshall in a former JOURNAL,* the difference being that a unit system has been used so that it may be applied to any conditions, the rate of interest has been changed, and a life for the pump of twenty-five years has been assumed, which makes the figures materially different from those where interest alone is considered. From this table it is obvious that under our circumstances it was economical to pay a large sum for high duty, and in our particular case we offered a bonus of $350 per million for duties above 150 million, with a penalty of $500 for every million below 150.

TABLE No. 2. — ANNUAL COST OF COAL FOR PUMPING 1 000 000 GALLONS OF WATER DAILY TO A HEIGHT OF 100 FEET, WITH COAL AT $5.00 PER TON (2 000 LB.).

This table gives sums the interest of which at $3\frac{1}{2}$ per cent. represents the saving effected by pumps of superior economy over an inferior one, assuming the life of the engine at twenty-five

* Vol. 11, p. 240, June, 1897.



BARR PUMPING ENGINE IN SILVER LAKE PUMPING STATION.

years, and establishing a sinking fund at 3½ per cent. interest to retire the first cost of pumps at that time. The table may be used in direct proportion for other heights, for other consumptions, or for other prices of coal.

Lower Duty.	Yearly Cost of Coal.	Higher Duty in Million Foot Pounds per 100 Pounds of Coal.									
		150	140	130	120	110	100	90	80	70	60
50	$1 522	16 920	16 300	15 600	14 800	13 830	12 680	11 270	9 517	7 250	4 233
60	1 268	12 680	12 070	11 380	10 570	9 600	8 450	7 030	5 283	3 020	
70	1 087	9 670	9 050	8 370	7 550	6 580	5 130	4 020	2 270		
80	951	7 400	6 780	6 100	5 280	4 320	3 170	1 750			
90	846	5 650	5 030	4 350	3 530	2 570	1 420				
100	761	4 230	3 620	2 930	2 120	1 150					
110	692	3 080	2 470	1 780	970						
120	634	2 120	1 500	820							
130	585	1 300	680								
140	541	620									
150	507										

NOTE.—Select the column headed by the higher duty. Then select the line beginning with the lower duty. The sum found at the intersection of the column and line is that which, under the above conditions, could be paid for the higher duty engine above the price of the lower duty engine.

PUMPING STATION BUILDING AND CHIMNEY.

The pumping station is well shown in the accompanying photographs. It is of red brick, the foundations of the pump room being of Portland cement concrete and of the boiler and coal room of granite. The pump, boiler, and chimney foundations are of concrete. The pump foundations extend four feet below the floor and are designed for a load of about one ton to the square foot, as are all the other foundations. This seems a very light load, but the material upon which we constructed was of a fine, wet, quicksandy nature, containing clay, and very unstable when unconfined. Space has been left for another pump, which would now be only for purposes of duplication, as it would be impossible to use the two in conjunction on account of the excessive friction head, although the size of the duplicate might be somewhat increased.

The chimney is of radial brick, 100 feet high, with an inside diameter of four feet at the top, there being no interior core above the common brick base 20 feet in height; this base is lined with radial brick of the same class as those in the chimney.

The boiler room contains two 264 horse-power water tube

boilers built by the Aultman-Taylor Company. They are of the well-known type made common by the Babcock & Wilcox Com-

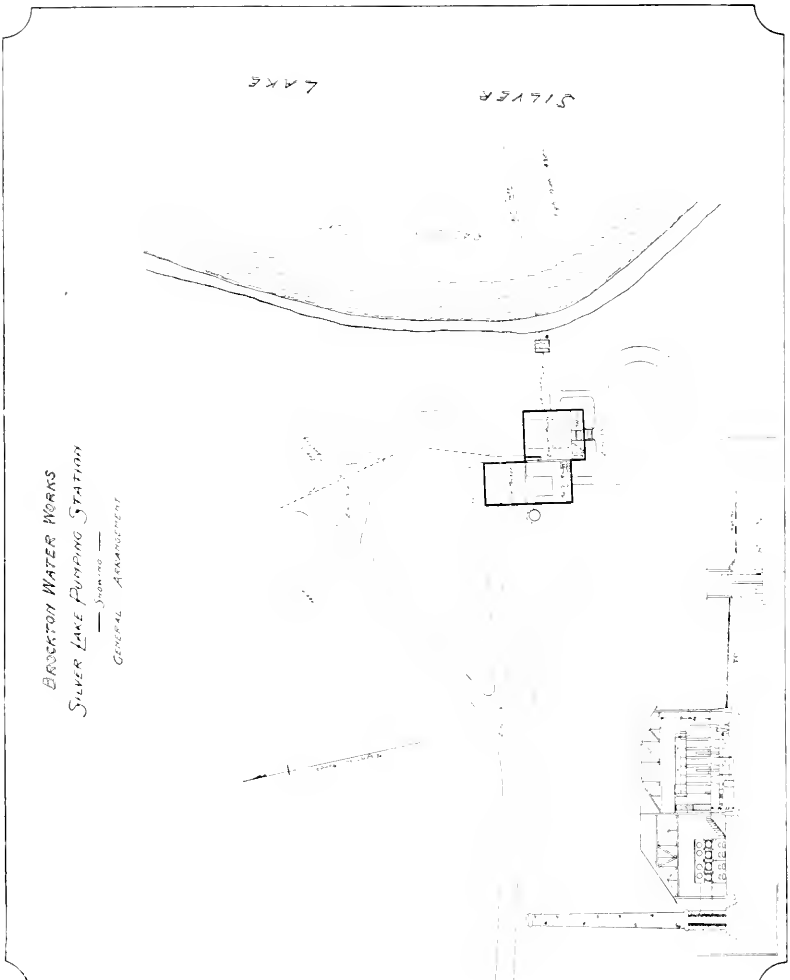


Fig. 4.
Scale of Plan, about 200 ft. to an inch. Scale of Cross Section about 100 ft. to an inch.

pany, and are insured to carry 160 pounds of steam. The coal room is 40 feet square and arranged to get the coal in at the top. A Green Economizer, to utilize the flue gases, is installed behind

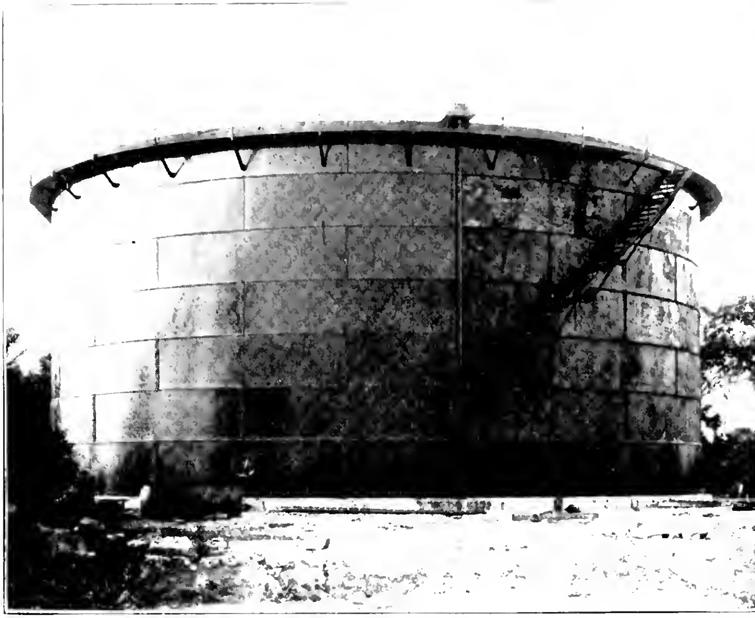


FIG. 1. NEW BROCKTON STANDPIPE.

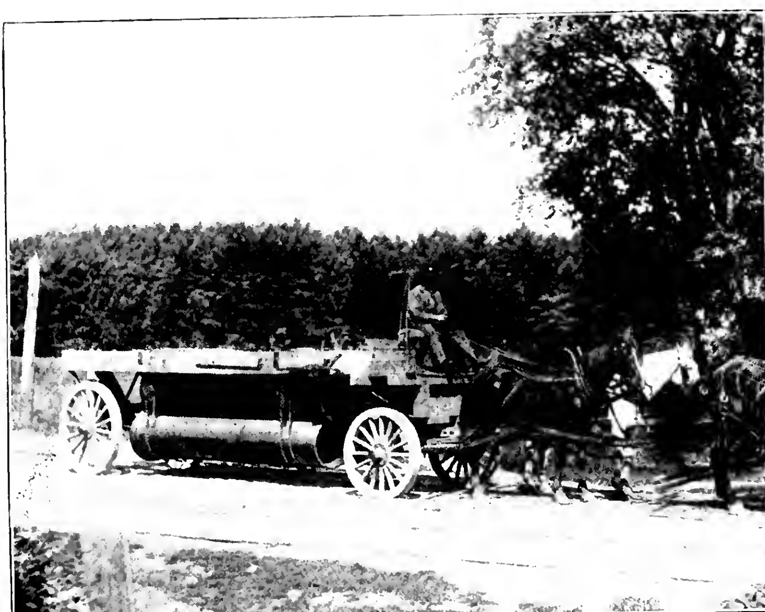


FIG. 2. PIPE WAGON.

the boilers, and heats the water about 100 degrees from about 90 degrees under ordinary conditions.

The pumps were furnished by the Barr Pump Company, and have a nominal capacity of 6 000 000 gallons per day. They are of the well-known vertical, triple expansion, crank and fly-wheel type, with cylinders 22, 36, and 59 inches in diameter, and three 19-inch water plungers, of 36-inch stroke. The valve area is 150 per cent. of the plunger area. The boiler feed pumps and air pump are attached to the low-pressure crosshead and have the same stroke. Condensing is done by a jet condenser. The steam cylinders are jacketed on the barrels, and the valves, of the Corliss type, are located in the heads; there are reheaters between the cylinders. The independent boiler feed, electric lighting generator, air compressor for cleaning boiler tubes, the repairing machinery and Green Economizer are all run by a small water motor discharging back to the lake.

The principal results of the duty test were as follows:

Principal Results.

Duration of trial, 10.30 A.M. to 8.30 P.M.	10 hours.
Total number of revolutions, by counter	20 118
Average revolutions per minute	33.53
Length of stroke, in feet	3 feet.
Average number of feet per minute piston travel	201.18

Temperatures.

Temperature of feed water	66°
Temperature of outer air for day*	71°
(Minimum, 56; maximum, 84.)	

Feed Water.

Total weight of water	46 753 pounds.
Leakage from boilers	375 pounds.
Total amount of water used by engines	46 378 pounds.

Pressures.

Steam pressure at throttle, by gage on engine	150.1 pounds.
(Corrected for water column.)	
Barometric pressure	14.61 pounds.
Absolute pressure	164.71 pounds.
Vacuum	25.8 inches.
Pressure by test gage on force main	119.5 pounds.
Difference between center of gage and water in pump well	20.9 feet.
Total water pressure (head)	128.6 pounds.

* At Brockton.

Duty. — Basis of 1 000 Pounds of Steam (Plunger Displacement).

$$850.5861 \frac{(128.6 \times 3 \times 20\,118 \times 1\,000)}{46\,378} = 142\,348\,630 \text{ foot-pounds.}$$

Capacity based on plunger displacement = 6 400 500 gallons per day.

A slip test of these pumps, using one of Mr. J. R. Freeman's calibrated 4-inch nozzles at a rate of about 5 200 000 gallons per day, indicated a slip of 2.8 per cent. (the fluctuations of the mercury column are well indicated by the following diagram, Fig. 5), and a later test made by pumping into the 75-foot diameter standpipe showed 2 per cent. slip, after allowing for leakage in the force main.

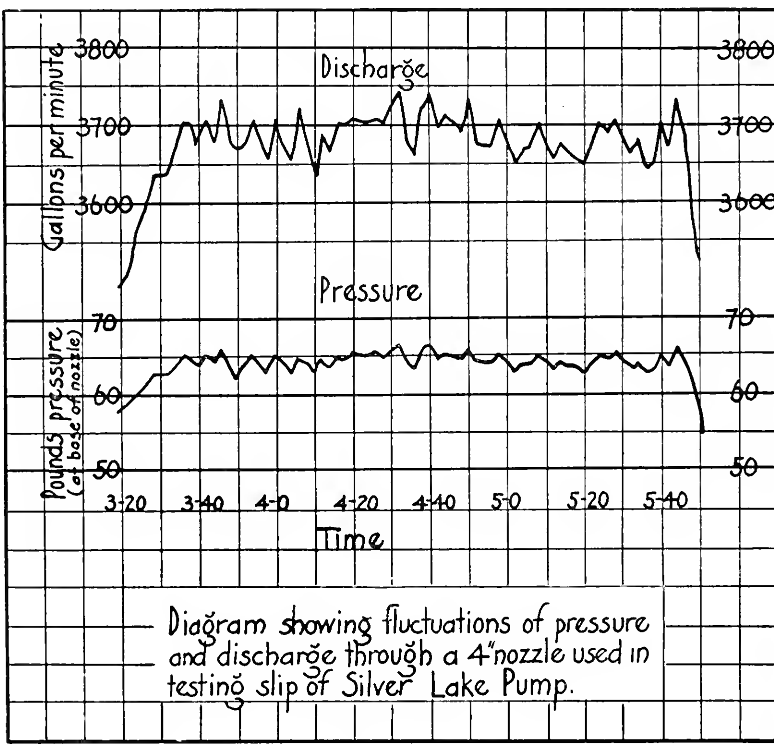


Diagram showing fluctuations of pressure and discharge through a 4" nozzle used in testing slip of Silver Lake Pump.

Fig. 5.

SCREEN HOUSE AND INTAKE.

The screen well is 12 feet in diameter, with a double set of ¼-inch screens in grooves, and is situated about 50 feet from the pumping station. This well presented the most difficult problem of all our work. Three-inch tongued and grooved sheeting was driven before digging began, and extended about 12 feet below the bottom of the well; the material was a fine quicksand, and boiled up nearly as fast as it could be removed, settling the ground to a distance of 50 feet in some directions. The intake pipe is 30 inches in diameter, is laid level, and extends 225 feet into the lake. Owing to our experience with the pump well, we did not attempt to pump out the sheeting in the lake, but excavated between the sheeting with a small orange-peel bucket and stiff-leg derrick, floated the last section of the pipe — 156 feet in length — which was headed up with wooden heads, and sank the pipe by admitting water through rubber tubes, it being necessary to excavate and make one connection where the two sections joined. The end of the pipe rests on a concrete block about 3 feet above the bottom.

STANDPIPE AND PRESSURES.

The need of more storage capacity led to the construction of a new standpipe 75 feet in diameter and 35 feet high, with spiral stairway and balcony.

The top of the new standpipe is 3 feet 4 inches higher than the old one, and their combined capacity is about two and a half million gallons, or (which is more important, as we seldom allow them to go down over 15 feet and never more than 20 feet) about 55 000 gallons per foot.

The highest part of the city is at an elevation only about 12 feet below the top of the standpipes, but the high portion is very limited in population, and we have a static pressure of 50 pounds on over 70 per cent. of the hydrants, only 6 per cent. having less than 30 pounds, with about 4 per cent. over 70 pounds. A much higher pressure would, of course, be desirable.

The construction of the standpipe presents no unusual features. It has concrete foundations 3 feet thick, projecting 1 foot above

the surface of the ground. It is constructed of mild steel having a tensile strength of 54 000 to 62 000 pounds per square inch. The work was done with a pneumatic gap riveter. It is composed of seven courses of plates, with lap seams.

The following table gives the thickness of plates and pitch of rivets, all horizontal seams being single riveted: there is a $6 \times 6 \times \frac{11}{16}$-inch bottom angle on the *inside*, and a $3\frac{1}{2} \times 3\frac{1}{2}$ angle iron on the outside, 18 inches below the top. It is designed for unit strains of 13 500 pounds per square inch on the plates, and 9 000 pounds on the rivets, which are of steel. The bottom is $\frac{1}{2}$-inch thick.

	Thickness of Plate.	Vertical Riveting.		
		Rows.	Size.	Pitch.
Course 1 . . .	$\frac{11}{16}''$	triple	$1''$	3.71″
" 2.	$\frac{5}{8}''$	"	$\frac{7}{8}''$	3.14″
" 3.	$\frac{1}{2}''$	"	$\frac{3}{4}''$	2.83″
" 4.	$\frac{7}{16}''$	double	$\frac{3}{4}''$	2.38″
" 5.	$\frac{3}{8}''$	"	$\frac{5}{8}''$	2.29″
" 6.	$\frac{5}{16}''$	single	$\frac{5}{8}''$	1.70″
" 7.	$\frac{5}{16}''$	"	$\frac{5}{8}''$	1.70″

The standpipe is equipped with the Winslow recording apparatus, run by a float in an 8-inch pipe resting on but not secured to the bottom of the standpipe. The 8-inch pipe is 4 feet from the side of the standpipe, and is held in place by two brackets, one at the top of the standpipe and the other 12 feet from the bottom, the latter being below the intended low-water mark. The 8-inch pipe is perforated by a small hole about 2 feet above the bottom, and has about 3 feet of oil in the top of the pipe to prevent freezing. The movement of the float is perfectly steady and is apparently absolutely unaffected by surface fluctuations.

The cost of the standpipe erected, with stairway and balcony, including two coats of paint, was \$10 550. The cost of the foundation, including excavation, was \$3 209.49.

Four bids for a concrete-steel standpipe, based on the designs of the bidders, were submitted, and the bids ranged from \$15 500 to \$19 000. The lowest bid was received informally after the

others were opened; had it been before us at the opening, it is a question whether we should not have accepted it.

Owing to a strong local feeling, and not to any particular prejudices of the writer, the whole work, with the exception of the chimney and standpipe, including the erection of the buildings, was done practically entirely by city labor, the laborers being paid $2.25 per day of eight hours. This work was under the sole charge of Mr. Horace Kingman, the superintendent of the water works, and was ably carried through within the original estimates, in spite of the high cost of pipe.

DISCUSSION.

Mr. Desmond FitzGerald. I came here to-day, Mr. President, to listen rather than to speak, and it is needless to say that Mr. Felton's paper has proved interesting. In connection with the Brockton work I remember after making my report I received an invitation to spend an evening with the mayor, aldermen, and common council to answer any questions they might see fit to propound. You may imagine there were some questions asked which were somewhat embarrassing. Among them I remember this: "You recommend taking water from Silver Lake, which is 14 miles away. Now, sir, suppose there was a river of pure water directly under the city, flowing away in large quantities; would that be a sensible thing to do?" Well, what kind of an answer could a man make to that question? Naturally, it would be a very short one, that it would be a very foolish thing to do. I afterwards was informed that a certain learned professor in Harvard had stated his belief that one of those underground rivers we hear about so often was running under Brockton to the sea, and all they would have to do to get a supply of water there would be to drive a pipe down and tap it. [Laughter.] It is a fact that this supposed stream kept action on Silver Lake in abeyance for several months.

I think that Brockton is very fortunate in having such a fine source of supply as this lake. I remember the clearness of the water and the sandy beaches around the border. It seems to me that, so far as the quality of the water is concerned, there are few cities or towns as fortunate.

I have made a great many active enemies in my life, I am afraid, but among the most active I recall now is the old anabena. He has attacked the Boston water supply several times and so vigorously that a person could not take a bath in the water with any pleasure, and no one would venture to use it in brushing his teeth. We didn't know much about him at that time, but we came very closely in contact with him and found good reason for shunning his acquaintance. I am, therefore, very much pleased to learn that the source of water supply I recommended to Brockton has only reached 128 per cubic centimeter. What would the people have thought if the number instead of being 128 had been 1 028 as I have frequently seen?

MR. MORRIS KNOWLES. I was especially interested in Mr. Felton's remarks about using second-hand pipe for laying the cable. We are laying considerable cable ourselves, and where we are not able to lay a tile conduit we have used tubing, understanding that it would be very difficult to draw a cable through pipe on account of their not being smooth at the joints. I should like to ask Mr. Felton how far apart the drawing-in manholes were, and if he experienced any trouble from injury caused in drawing-in.

MR. FELTON. No; we had no difficulty whatever, and never discovered that there was any mechanical injury to the cable. The drawing-in stations were about 500 feet apart. We thought of the possibility of injury and considered seriously whether we shouldn't lay the cable without any covering, except in the streets. There is quite a large portion of the line over private land and through woods, and the pipe is only to prevent mechanical injury. When we first got the thing finished, as we thought, we couldn't make it work for a while. We suspected it was the fault of the man who made the joints, so we had some one go over the line and inspect them, and he found some that were weak; it was claimed water had got into them, and since they have been made right it has never failed to work in good shape. The recording apparatus has worked satisfactorily, although we have a little trouble with the float on account of the lengthening of the string. It is supposed to record every 3 inches, and it hasn't been more than 9 inches out at any time, but it has been as much as that. We can't depend upon it within 6 inches, on account of the float slipping on the wheel or possibly a little slipping of the string.

Mr. FitzGerald. I should like to ask what the nozzle pressure of that 4-inch stream at the lake was.

Mr. Felton. The nozzle pressure was about 62 pounds and the pressure at the pumps was about 140, the difference being lost in friction.

Mr. FitzGerald. What was the horizontal distance of the stream above the lake?

Mr. Felton. I am sorry to say we didn't get a good measurement of that, and I can only judge by the photograph. I should say the bulk of the stream was very nearly 200 feet, but it broke up a good deal, as you noticed in the slide, giving a very beautiful effect, with rainbows, etc.

A STUDY OF SOME VITAL STATISTICS.

BY L. M. HASTINGS, CITY ENGINEER, CAMBRIDGE, MASS.

[*Read November 14, 1906.*]

Nature has implanted in every sane person a desire to live, to prolong life, and pursue, as far as possible, health, and the capacity for enjoyment. The old story of Ponce de Leon seeking the fountains of eternal youth but illustrates the real desires of every human being, and typifies, in its story of search and struggle and final disappointment and defeat, the ceaseless effort of the human race to find some way by which the dread ravages of disease may be averted and the relentless hand of death stayed.

While the fabled "Fountain of Eternal Youth" has never been discovered, nor that magic potion which it was believed should forever preserve health and beauty been compounded, — at least in any such manner as the ancients thought possible, — nevertheless very much has been done in these later years not only to lengthen the average of human life, but to increase its capacity for productive work and enjoyment. Of the many causes which have tended to produce this result, perhaps the two most prominent are the marvelous progress made in medical discovery in the knowledge of the causation of many diseases, with an increased efficiency in its prevention or cure, and in sanitary science a far better understanding of the effect upon health of environment, — soil, climate, temperature, cleanliness, drainage, etc., — and the hygienic value of good food, water, and air.

In the field of medical discovery the most potent factor in producing the remarkable results obtained is the work of highly trained specialists and experimenters in natural and medical science. It would be difficult to overestimate the debt which the world owes to these scientific men who, by patient investigation and research, extending often through long years of poorly paid labor, have made discoveries and established theories

the application of which will be of incalculable benefit to mankind. This is all the more noteworthy because in many cases the amount of laborious experiment and research necessary to establish a single fact of importance is enormous, and the degree of scientific skill and intelligence required the highest.

Think, for instance, of the time and labor and patient investigation required to discover and demonstrate — what is now generally accepted as correct — the general theory of the germal origin of many diseases. How can the world repay Robert Koch, of Germany, who, perhaps more than any other one man, advanced the knowledge of bacteriology in its relation to disease, or Louis Pasteur, of France, who developed the method of cultures of these bacteria so that they could be readily examined or studied, and later discovered a remedy for that terrible malady, rabies, or hydrophobia, so that the mortality from the disease has been reduced from 60 to 80 per cent. to less than 1 per cent.?

Think of the work of Klebs and Löffler in Germany, in determining the bacteria of diphtheria, and of Behring in Germany and Roux in Paris in perfecting the antitoxin treatment for this terribly fatal disease, saving thousands of otherwise doomed victims.

As a result of the labors of these and a great many other men — physicians, chemists, bacteriologists, biologists, sanitary engineers — who have devoted themselves unselfishly to the cause of bettering humanity on its physical side, we have to-day advanced far on the road to a proper understanding of disease, its cause, prevention, and cure. We have also, in many ways, a far better and more rational standard of living than before; better food, better houses, purer water, and better sanitary conditions in cities and crowded areas. One of the most striking demonstrations of the efficiency of this increased knowledge concerning disease of which we have been speaking is the decreased number and virulence of the outbreaks of contagious diseases and their greatly lessened mortality; smallpox, yellow fever, cholera, diphtheria, the plague, and similar diseases, have now no such terrors as formerly.

Another evidence of the practical value of this increased knowledge of sanitary and medical matters is a *lowered annual death*

rate. I believe that this result is pretty general throughout this country; it certainly appears in the statistics which I have examined, being most marked in the last decade, and especially in the *cities.* Now this lower annual death rate indicates a *longer average life* to the individual, with all its possibilities for enjoyment and for usefulness to the community. It also indicates a lessened *morbidity* or sick rate, with its burden of expense and lessened earnings.

Another fact worthy of notice is that this lowering of the death-rate has been largely among the *young*, or persons under five years of age, with the expectation of a long life before them. As will be shown, the greatest mortality occurs among the very young, and decreases as the age advances until about the fifteenth year, when the death-rate begins to rise again. If, therefore, the young can be carried over this period of greatest danger, their expectancy of life will be greatly increased.

It is to the credit of the new knowledge that this is exactly what has happened. The average annual death rate in Cambridge among children under five years of age for the thirty years from 1850 to 1879 was about 9.00 per 1 000 of all persons living, while for the ten years 1894 to 1903 it was only 6.08 per 1 000, a decrease of about 33 per cent.,— a very excellent showing.

The figures which I have prepared relate largely to Cambridge, but I think that in a general way the results are typical of those which obtain in cities in many parts of the country. Free use has also been made of the statistics given by Mr. Robert Moore in his excellent paper on "Vital Statistics of St. Louis since 1840," published in the *Journal of the Association of Engineering Societies*, November, 1904. They are used simply as an interesting comparison between localities remotely situated.

Climatic conditions, as indicated by temperature and rainfall, have an important effect on health and happiness, and so Fig. 1 is given, showing the precipitation and average temperature readings at New Bedford, Mass., 1813-1904. These are said to be the longest and most reliable set of meteorological observations taken in New England, being made entirely by Mr. Samuel Rodman and son for the time 1813 to 1904. A study of this plate would seem to show that while there has been some variation of

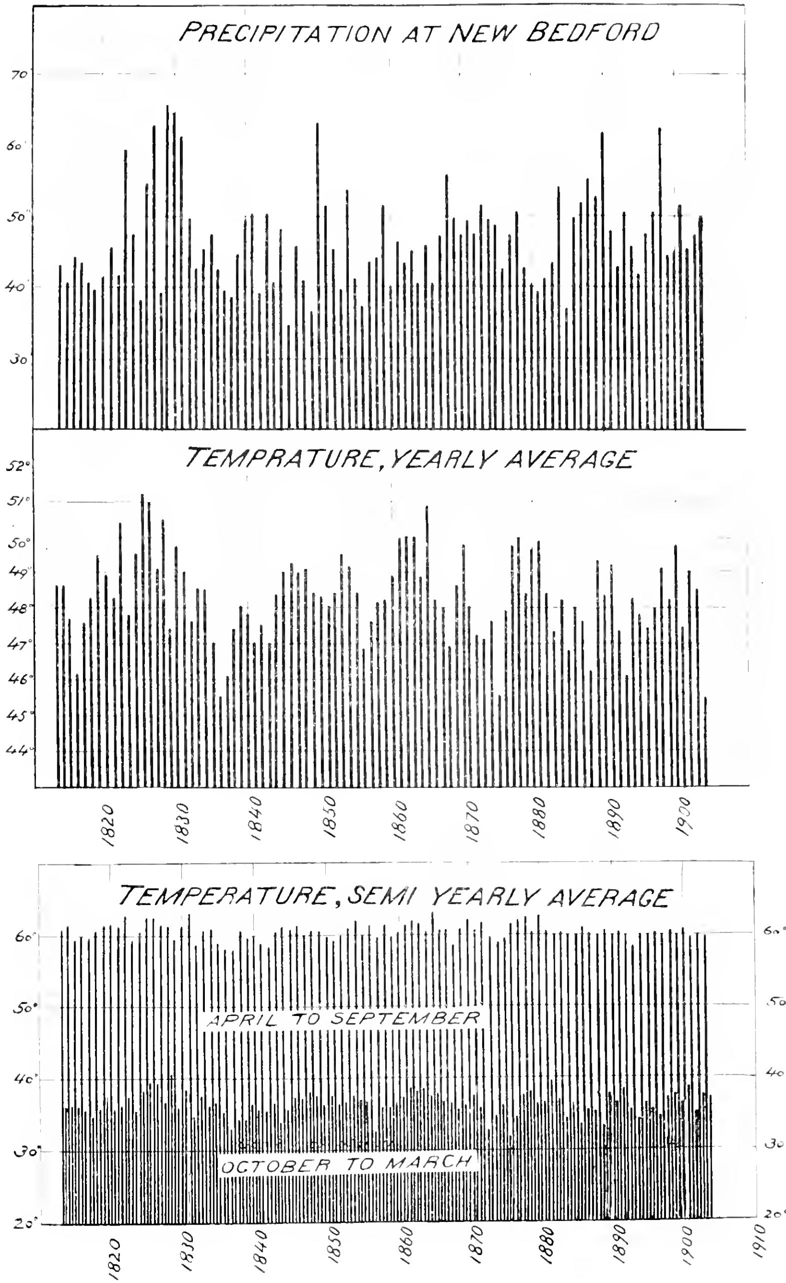


FIG. 1. CLIMATIC CONDITIONS AT NEW BEDFORD.

temperature in short periods, yet as a whole the average temperature has not changed. The low winter temperature of 1836 should be noted; also that of 1841. It was on February 3, 1844, that the Cunard steamer *Britannia* had a channel cut through the ice of the harbor and was towed to sea with United States mails, etc. The ice extended nearly to Fort Warren. The winters of 1856 and 1875 were also notably severe.

With regard to precipitation, excepting a short period at about 1830 of abnormally large precipitation, there seems to be a tendency in this record to show an increase in the average annual amount, the average by ten-year periods being as follows:

1813 to 1820,	41.67 inches.
1821 to 1830,	51.95 inches.
1831 to 1840,	45.96 inches.
1841 to 1850,	44.94 inches.
1851 to 1860,	44.76 inches.
1861 to 1870,	46.26 inches.
1871 to 1880,	46.87 inches.
1881 to 1890,	48.69 inches.
1891 to 1900,	47.87 inches.
1901 to 1904,	48.69 inches.

Population is the basis of all vital statistics, so Fig. 2 shows the growth of population of Cambridge, Lowell, and Worcester.

Fig. 3 shows the curve of population growth for the state of Massachusetts, 1765–1900; note that in this state there have been three different rates of growth. From 1765 to 1830 the rate of increase was small, the curve running quite low, the yearly increase being only about 5 750. Rapid immigration and the development of manufactures in the next period, 1830 to 1885, brought the rate to 26 765 per year, a very marked increase; while from 1885 to 1900 the rate of increase has been 57 545 per year.

Fig. 4 shows the Cambridge birth-rate per 1 000 inhabitants. Attention should be given to the low rate indicated during the Civil War, 1861 to 1865, and also during the period of great financial depression, 1875 to 1879. The birth-rate from 1850 to 1859 was 37.83, while the rate from 1894 to 1903 was 29.54, a decrease of

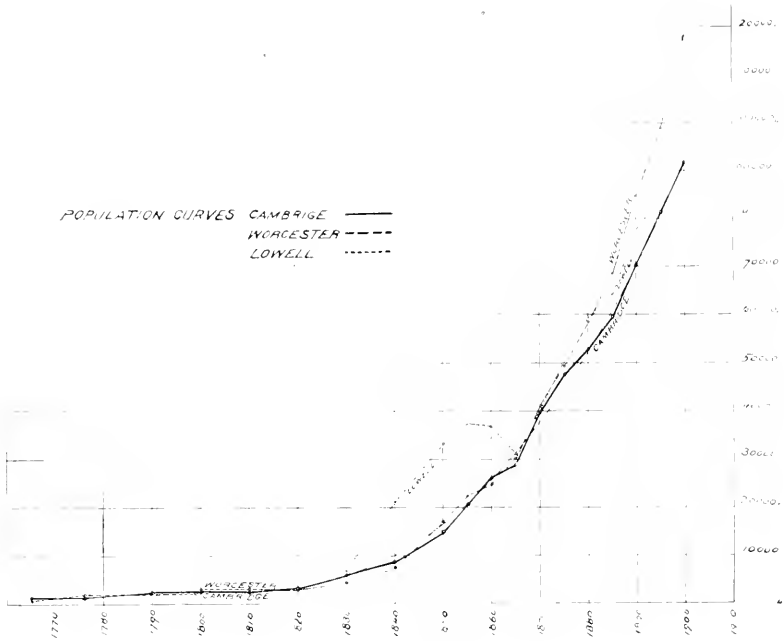

POPULATION CURVES CAMBRIGE
WORCESTER
LOWELL

FIG. 2.

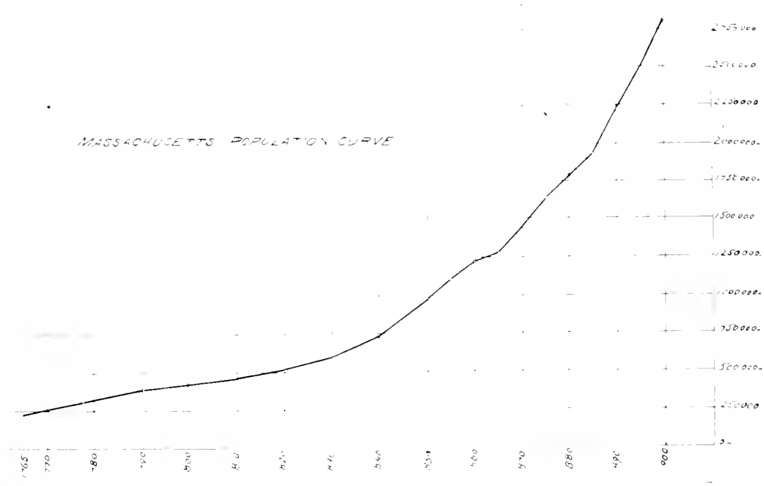

MASSACHUSETTS POPULATION CURVE

FIG. 3.

22 per cent. The decrease in the rate for the state of Massachusetts for the same ten-year periods was from 29.09 to 26.39, or over 9 per cent.

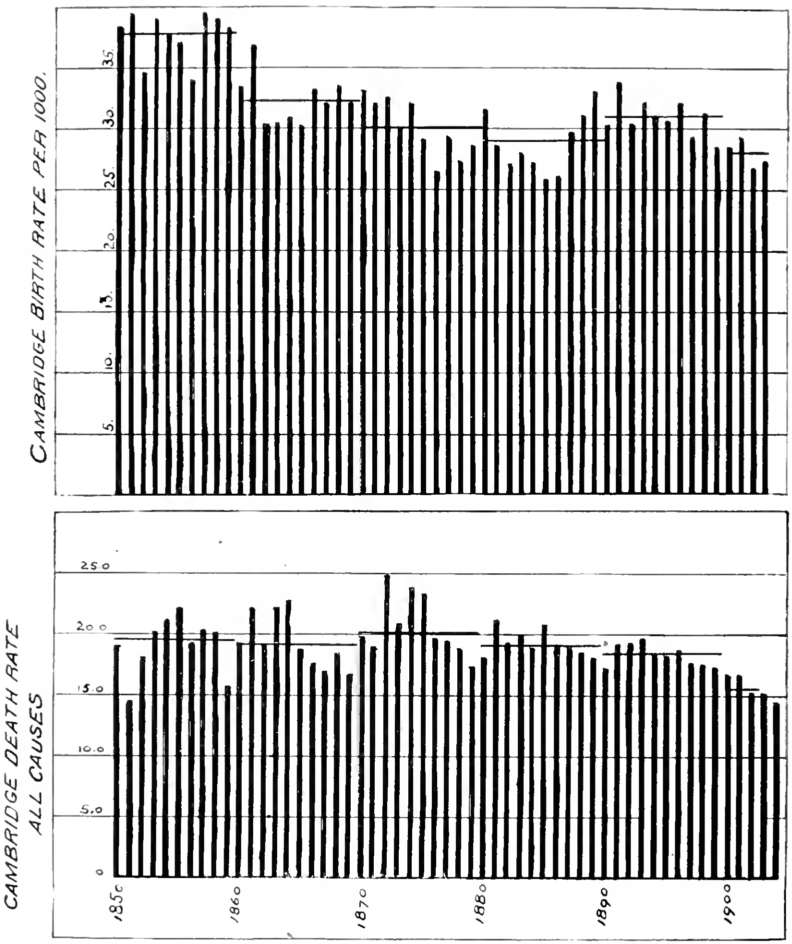


FIG. 4.

On Fig. 4 is also shown the Cambridge death-rate from all causes for the last fifty years. By ten-year periods the average rate is:

Period.	Death-Rate.
1850–1859	19.67
1860–1869	19.44
1870–1879	20.22
1880–1889	19.27
1890–1899	18.52
1895–1904.	16.81

the last a reduction of 15 per cent. from that of the period from 1850 to 1859.

To get an approximate idea of what this decrease in the death-

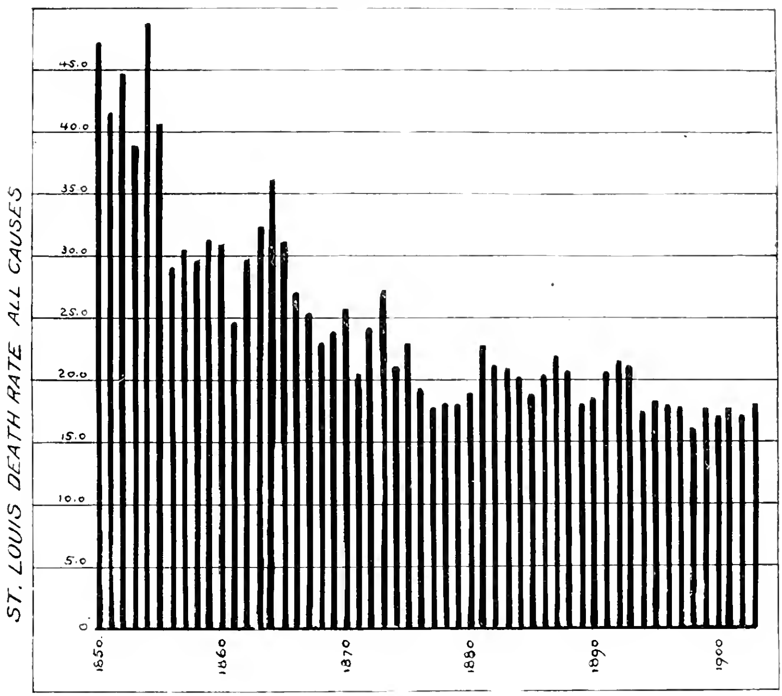


FIG. 5.

rate means, let us assume, as is sometimes done, that the average length of life is represented by the death-rate. Thus in the decade 1850–1859 a rate of 19.68 would represent an average duration of life of 50.3 years, and for the period 1895–1904 a rate of 16.81

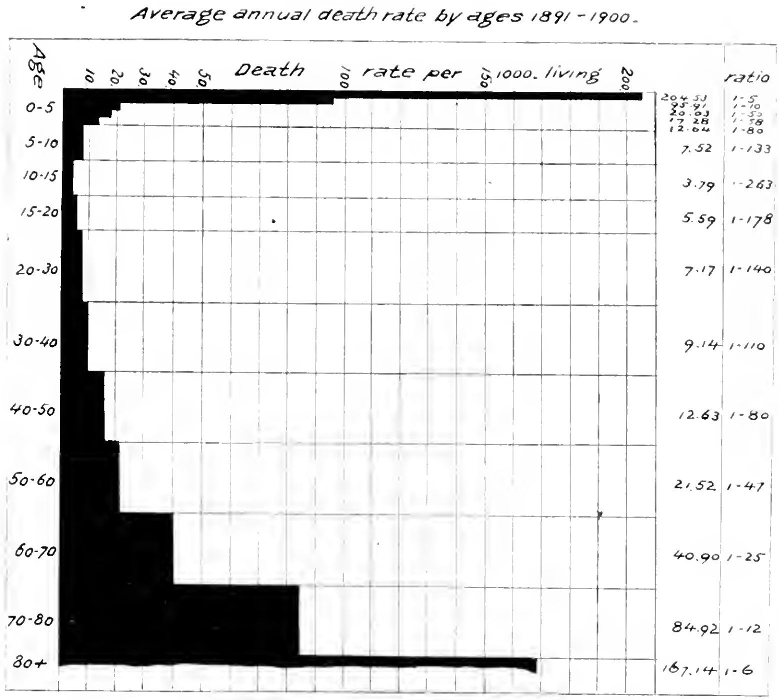
would represent an average life of 59.5 years, a gain of 9.2 years. Who can estimate the value of this lengthened life? Or, look at it another way. If the death-rate of the first period had been maintained till the present time, the total number of deaths in 1904 would have been 1 980. As a matter of fact, however, the total number of deaths was only 1 444, or 536 less than would have occurred if the early rate had continued, being just so many lives *saved*. If, now, we give to each life its legal valuation of \$5 000, we have \$2 680 000 as the total value of the lives saved for the year 1904 alone in the city of Cambridge.

This large decrease in death-rate seems to apply to most of the cities of the state, and considerably exceeds the decrease in death-rate for the state as a whole as given in the census reports. For the period 1850–1859 the rate was 18.25, and for 1894–1903 the rate was 17.80, a decrease of only 2.4 per cent. The death-rate for the cities seems to start higher and end lower than the rate for the whole state, probably due to the balancing influence of the rural districts where the first conditions would be likely to be better and less improvement would be expected.

Fig. 5 shows the death-rate from all causes for St. Louis, 1850 to 1904. This shows a remarkable reduction in the rate, from 43.08 per 1 000 for 1850 to 1859, to 71.71 per 1 000 for 1894–1903.

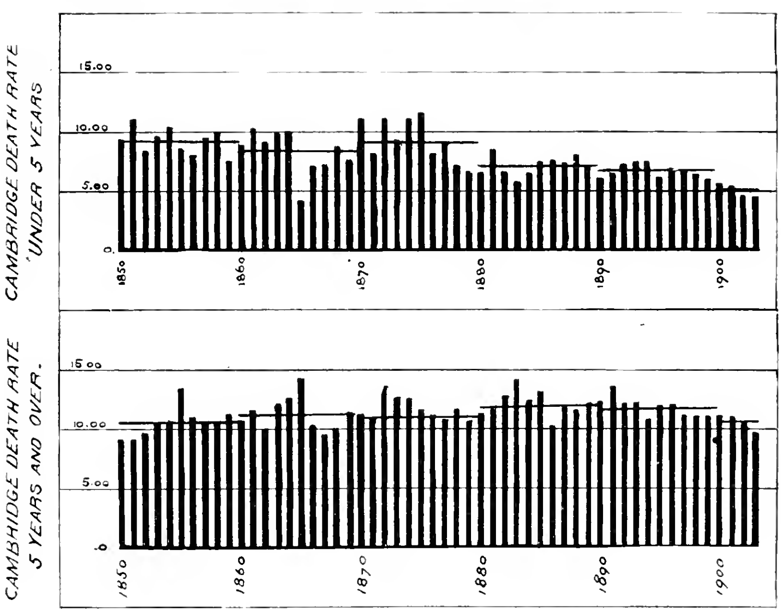
Compare (for what they are worth) the death-rates of several cities of nearly the same population as Cambridge. These rates are the average for the ten years 1894–1903.

City.	Population.	Death-Rate.
Lowell, Mass.	94 969	20.24
Albany, N. Y.	94 151	19.44
New Haven, Conn.	108 027	17.29
Worcester, Mass.	118 121	16.87
Cambridge, Mass.	91 886	16.81
Hartford, Conn.	79 850	16.24
Syracuse, N. Y.	108 374	13.48
Dayton, Ohio	85 333	13.35
Grand Rapids, Mich.	87 565	12.04
St. Louis, Mo.	575 238	17.71



Average annual death rate by ages 1891 - 1900.
Age
Death rate per 1000. living
ratio
0-5
5-10
10-15
15-20
20-30
30-40
40-50
50-60
60-70
70-80
80+
7.52 1-133
3.79 1-263
5.59 1-178
7.17 1-140
9.14 1-110
12.63 1-80
21.52 1-47
40.90 1-25
84.92 1-12
167.14 1-6

FIG. 6.



CAMBRIDGE DEATH RATE UNDER 5 YEARS
15.00
10.00
5.00
0.
1850
1860
1870
1880
1890
1900
CAMBRIDGE DEATH RATE 5 YEARS AND OVER.
15.00
10.00
5.00
.0
1850
1860
1870
1880
1890
1900

FIG. 7.

Fig. 6 shows the death-rate per 1 000 persons living of the given ages in Cambridge (1891 to 1900). The figures are as lows:

Age.	Death-Rate.	Mortality.
Under 1 year	204.53	1 in 5
1- 2	95.91	1 ,, 10
2- 3	20.03	1 ,, 50
3- 4	17.28	1 ,, 50
4- 5	12.61	1 ,, 80
5-10	7.52	1 ,, 133
10-15	3.79	1 ,, 263
15-20	5.59	1 ,, 178
20-30	7.17	1 ,, 140
30-40	9.11	1 ,, 110
40-50	12.63	1 ,, 80
50-60	21.52	1 ,, 47
60-70	40.90	1 ,, 25
70-80	84.92	1 ,, 12
over 80	167.14	1 ,, 6

Note the terrible mortality of children under one year of age, more than one in five dying.

On Fig. 7, however, it is shown that this mortality rate for children under five years of age is being reduced, the rate by ten-year periods being as follows:

Period.	Death-Rate of Children under Five.	Period.	Death-Rate of Children under Five.
1850–1859	9.26	1890–1899	6.77
1860–1869	8.33	1894–1903	6.08
1870–1879	9.25	1900–1903	5.10
1880–1889	7.25		

The last a decrease of 34 per cent. in child mortality from the period 1850–1859.

It should be remembered that these figures relate to the whole population of all ages, whereas children under five form about one tenth of the whole population, and these figures should, therefore, be multiplied by ten to obtain the rate for that age.

Fig. 7 also shows the death-rate in Cambridge for persons five

years of age and over. The rates are successively 10.69, 11.28, 11.05, 11.92, 11.76; 1900–1903, 10.62; and 1894–1903, 11.04, showing little change in the death-rate for adult persons.

Fig. 8 shows the death-rate due to croup and diphtheria combined for both Cambridge and St. Louis. In Cambridge the rate in 1880–1889 was 1.316 and in 1894–1903 was 0.626, or a

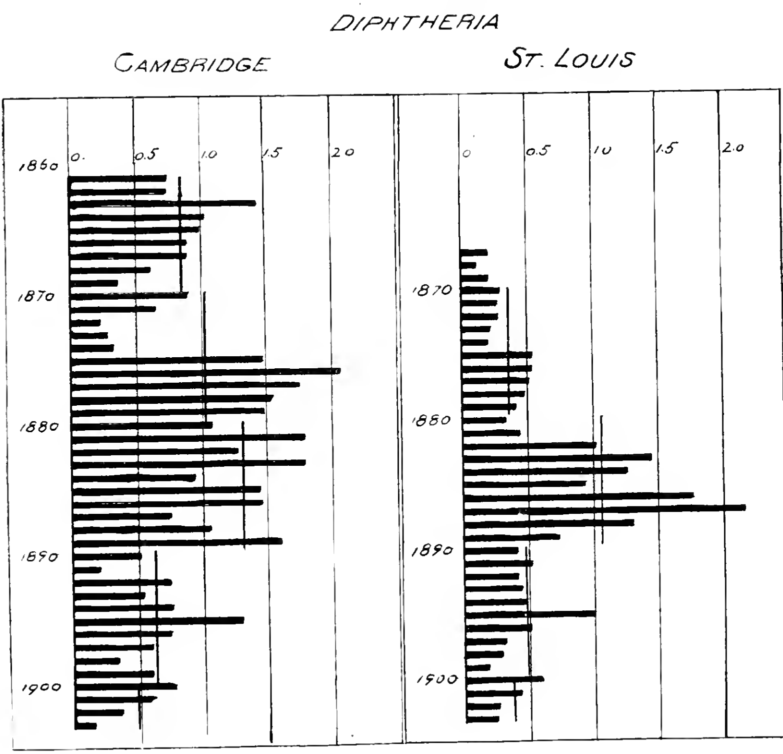


FIG. 8.

decrease of 52 per cent. St Louis shows a reduction from 1.152 to 0.435, or 62 per cent. This is undoubtedly largely due to the introduction of the antitoxin treatment. Professor Welsh states that in something like 5 000 cases of diphtheria, the history of which he examined, the use of the antitoxin treatment had reduced the mortality more than 50 per cent., while in Berlin the death-

rate from this disease was reduced from 10.2 per cent. to 3.7 per cent., and in Paris from 6.5 per cent. to 1.3 per cent.

Fig. 9 shows the death-rate from typhoid fever for Cambridge and St. Louis. In Cambridge the maximum rate occurred in

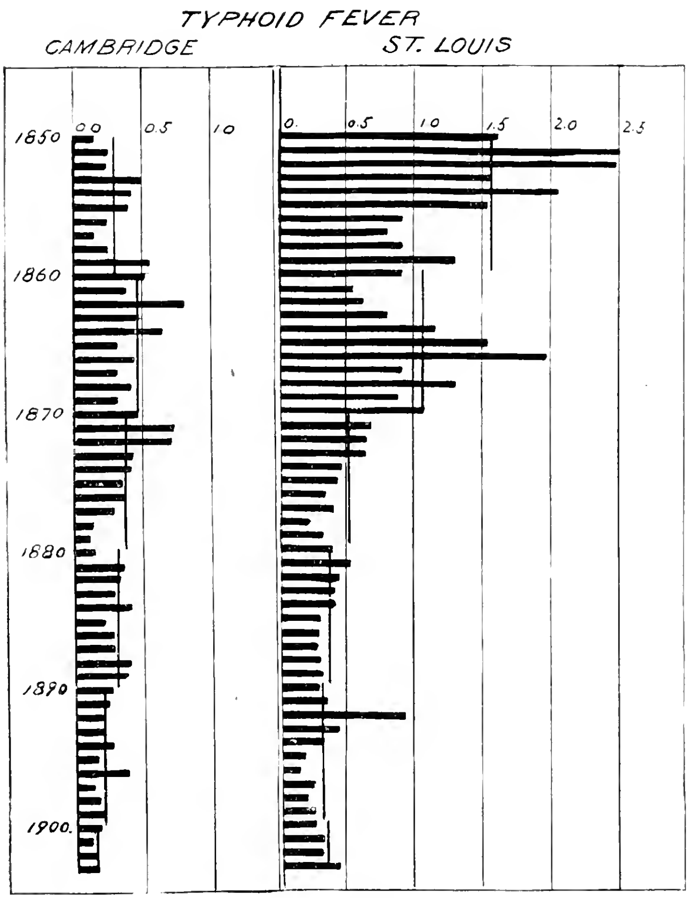


FIG. 9.

1860–1869 at 0.456 per 1 000. The rate for 1894–1903 was 0.189, a reduction of 59 per cent. The St. Louis diagram is a very instructive one, as showing the influence of the sanitary condition of the water supply on the typhoid fever death-rate.

Mr. Moore, in his paper, states that the first water works for St. Louis were built in 1832, supplying a small amount of water from the Missouri River. Most of the inhabitants used water from wells until 1855, when the water works were enlarged and a more general use of river water was made, with a decrease in the typhoid death-rate until about 1863. About this time the construction of sewers discharging into two creeks connecting with the river above the pumping station was active and its effect is shown in an increase in the death-rate.

In May, 1871, the old water works were abandoned and moved up the river above the point when any sewage then entered the river. This produced another lowering of the rate until 1890, when it began to rise again. This was caused by the introduction of sewage into the river near the pumping station. In 1892 the city set some pumps on one of the creeks which was particularly dangerous, and pumped the water which was polluted over into a sewer which discharged below the pumping station. The rate again fell off so that in 1897 it was the lowest ever recorded in St. Louis.

The rise to the rate shown for 1900 is probably caused by the increasing amounts of sewage from the six cities on the river above St. Louis, and, it has been claimed, from Chicago itself and its great drainage canal.

Consumption causes, it is said, one seventh of all the deaths in the world. In Cambridge it causes about 12 per cent. of all deaths. There has apparently been improvement in the rate for this disease, although the figures must be taken with some caution, due to uncertainty as to the correctness of the returns of causes, many objecting to have the cause of death assigned as "consumption" as affecting insurance, and other interests. The average rates as given by the returns are as follows:

Period.	Death-Rate. from Consumption	Period.	Death-Rate. from Consumption.
1850–1859	3.901	1890–1900	2.336
1860–1869	3.116	1900–1903	1.962
1870–1879	2.930	1894–1903	2.016
1880–1889	2.948		

a gain of 47 per cent.

Not only does the disease cause a formidable portion of the deaths, but its victims are largely those in middle life, the period of largest death-rate being from twenty to forty years of age.

The returns of pneumonia are so unsatisfactory that no diagram

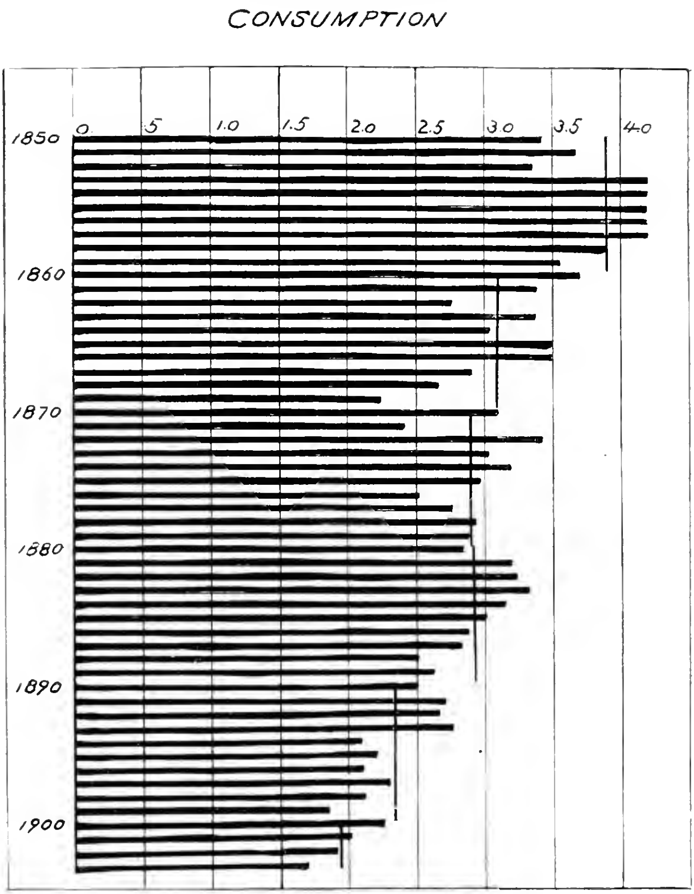


FIG. 10.

was made, — the figures as obtained, however, seem to show an increase in the rate from this disease in Cambridge. This is confirmed by the figures of St. Louis. The figures for Cambridge, as I have them, are

Period.	Death-Rate from Pneumonia.	Period.	Death-Rate from Pneumonia.
1872-1879 . .	1.33	1890-1899	1.60
1880-1889	1.69	1900-1903	1.760

We have now seen, from the figures and diagrams presented, something of the results which have been accomplished in the last fifty years in the effort to solve the great problem of the conservation of human life.

It seems certain that in this period the danger of recurrence of great epidemics has been greatly lessened, that the mortality from many contagious diseases has been greatly reduced, and that on the whole the average length of human life has been increased. As to how far this improvement may be carried in the future, it does not seem too much to expect that, with our constantly increasing knowledge, and attention to the details of sanitary conditions and hygienic living, the improvement will continue, and that at no distant date we may have a death-rate considerably lower than the present one. We can never hope to banish *entirely* disease and death, even if it were desirable, yet there are many lines along which improvement can be made in things pertaining to public health, and by which not only may the *length of life* be increased, but its *vigor*, *activity*, and *capacity for useful work* augmented.

It does not seem, for instance, that *consumption* can for long continue the great scourge that it now is to the human race, cutting down so many in middle life, but that with all the study and investigation now being given to the pathology of this disease, it is not unlikely that some definite and efficient treatment will be found, by which the " bacillus tubercle " will be overcome and mankind will be comparatively free from this disease.

It is probable that at no distant day most, if not all, the water furnished by public water supplies will be thoroughly purified by some form of filtration, either mechanical or through layers of sand, as is now being done at Albany, Pittsburg, Philadelphia, and many foreign cities, giving a water practically free from the

"bacillus coli" and other bacteria, and thus help to materially lower the *typhoid fever* death-rate.

It may be that even the *air supply* of all buildings where people live or are employed will be purified and cleansed, and the gas, dirt, smoke, and floating germs literally washed out, as is now done at the city hall in St. Louis, Mo., reducing the liability to throat and lung diseases.

The immediate removal of *sewage* and *garbage*, and its disposal without offense and without danger, is another serious problem which should find some satisfactory solution. It may be, too, in that future time of which I speak, that *free public baths* will be furnished by all municipalities, open the year round, and that daily bathing in these, or in a private bath, will be made compulsory, the same as attendance at the public schools or vaccination now are.

Think what this would mean, from a sanitary standpoint, to the "great unwashed," to say nothing of how much it would contribute to the esthetic olefactory senses of the patrons of many of our street car lines at certain hours of the day!

It may be, too, and this seems the hardest of anything to believe or expect, that we shall some time learn to eat and drink only so much as we need, and then only of such things as are good for us. When that time comes, it may be expected that the public health will be so good that the practice of medicine will be a lost art, and these figures and mortality tables will have to be completely revised and corrected.

DISCUSSION.

PRESIDENT SEDGWICK. It has been said that the one incurable disease is old age, but when you look at the statistics you will find that only a small proportion of deaths is given as from that cause. People seem to die of everything except old age, only about 4 or 5 per cent. being put down to that. But such a percentage is apparent rather than real. A good many people die of pneumonia, for instance, who really die of old age — that is, who would not have died of pneumonia if they had not been enfeebled by age.

There are many aspects of this subject which will bear serious thought. The chart of mortality at different ages is particularly

valuable and interesting. I have one very much like it, a lantern slide, for Berlin, Germany. It is higher in the infant mortality than the one shown by Mr. Hastings. One of the striking things which appears from the study of that subject is that infants fed on cow's milk — bottle-fed infants — die at a much higher rate than those that are breast fed. There is an infinite amount of work which can be put into all these diagrams and studies.

It seems to me it is well to have such things brought before us now and then, just to remind us of the actual facts of life and of the tendencies of the times. In these tendencies this association has played an important part in Massachusetts by seeing to it that the water supplies are made purer and better; thereby reducing not only typhoid fever but some other diseases, because there is a good deal of evidence now-a-days that a number of diseases are water borne, which we did not formerly consider water borne, — not, of course, borne with the same readiness and to the same extent as typhoid fever, but still sufficiently to cause a good deal of trouble.

Mr. Frank L. Fuller. I think we owe a great deal to Mr. Hastings for the labor he has put into this paper. The results of his work are very instructive indeed and will be very valuable and interesting for purposes of future reference and comparison. I should like to ask Mr. Hastings whether he has made an enumeration of deaths from accidental causes.

Mr. Hastings. No, sir; I didn't go into that.

Mr. H. A. Miller. I understand that the death-rate among infants was much greater formerly than in later years, and at the same time the birth-rate has decreased. If the birth-rate had remained as it was, would the death-rate have remained the same, or would it have been greater or less?

Mr. Hastings. The death-rate I gave for infants was for the infants living, so it wouldn't make any difference how many there were, the rate would be the same. The diagram I showed you gave the death-rate of children under one year, living at that age, and the death-rate of children under two years, living at that age, so the number would not have any effect.

Mr. Miller. I probably did not make myself understood. The death-rate among infants, as I understand it, is smaller than it used to be, while the birth-rate also has decreased. That is, you

gave us the total death-rate of all ages, as I remember, and that has decreased?

MR. HASTINGS. Yes, sir.

MR. MILLER. Now, if the birth-rate had remained normal, or remained the same as it originally was, would the death-rate total be in proportion, or would it have decreased as shown by you? Do you get an idea of what I mean?

MR. HASTINGS. I think so. I think if there had been more children the death-rate of all ages would have been higher, because the mortality among children is larger.

MR. MILLER. Would it have been the same practically as it was originally?

MR. HASTINGS. I couldn't say as to that, but I don't think so.

THE PRESIDENT. Perhaps I may say a word about that, as I happen to be more or less familiar with the subject. A high birth-rate is generally supposed to favor a high death-rate, and yet, if the birth-rate had remained as it used to be, it is not likely that the infant death-rate would have been as high as it then was; although it would have been higher than it now is.

MR. DESMOND FITZGERALD. I will say a single word in regard to the population curve shown on the diagram. Some time ago I had occasion to examine very carefully the increase in population of all the principal cities of the United States for the city of Oakland, Cal., on a subject connected with their sanitary works, and I found that of all the cities in the United States the city of Worcester had increased from the beginning of its records to the present time in the most regular way, showing an almost perfect curve. The city of Providence, I think, came next, and was very similar.

MR. ROBERT J. THOMAS. I should like to ask whether in taking the population of Cambridge the students in Harvard College were included?

MR. HASTINGS. I think so. They are enrolled as living in Cambridge, although very few are voters there. There has been quite a discussion about that, whether students who are enrolled as inhabitants of Cambridge really have a domicile or residence there. They are included as inhabitants, but, generally, not as voters.

MR. THOMAS. They come into the population statistics?

MR. HASTINGS. Yes; and that would explain somewhat the rate

of our increase in population. We have about 5 000 students, and they are not expected to contribute much to the birth-rate.

THE PRESIDENT. Mr. Mills has drawn a very interesting curve for Lawrence, by which he has shown that the introduction of the filter in 1893 was followed by a very marked increase of population and decrease of the total deaths. It is one of the most instructive curves I have ever seen. I do not remember the exact figures, but the gist of it is that, assuming the total number of deaths in Lawrence in 1892 as 1 000, and it was going rapidly up by a line which would diagonalize that chart, when the filter was introduced the line changed its direction altogether, so that after ten years the total number of deaths in the city was no greater than it had been in 1892, and that, too, although the population had increased meantime 50 per cent. It is a very extraordinary showing as to the effect of a purified water supply upon the public health.

MR. MORRIS KNOWLES.* There is something which occurs to me, which may be of interest in teaching us not to draw conclusions too quickly, unless we know all the facts. An instance which occurred in our city of Pittsburg during the last year illustrates this. As you all know, it is the city which leads all others in death-rate and sickness from typhoid fever. For some years past the average reported cases of sickness per 100 000 has been 750 to 800, and the cases are generally recorded. During the past year, through the energetic efforts of the head of the bureau of health, it has been made manifest to every one that it is not wise to drink water from the municipal supply. Notices have been posted in the street cars and in the public buildings, office buildings and other places, that the city water should be boiled before it is used for drinking. In buildings where good water is furnished, that fact is placarded, so that people will know that the water is safe.

Now it is not probable that there has really been a twofold increase in the number of typhoid cases within the past few years. There has probably been some increase, but I doubt if the increase has been anything like what it appears from the statistics to have been this year. The statistics so far show that there have been about twice as many cases of typhoid fever in the city as ever before. In other words, instead of being 750 or 800, there will probably be

* Chief of the Bureau of Filtration, Pittsburg, Pa.

reported 1 400 per 100 000, while the deaths will remain about the same as heretofore; that is, the death-rate this year will be about 10 per cent. instead of 15 to 18 per cent. The probable explanation is that it is popular now to report diseases as typhoid which are doubtful; and formerly not all were reported which should have been, and it shows that it is not always safe to trust statistics unless one knows the facts.

THE PRESIDENT. That applies to cases rather than to deaths, because deaths are much more accurately reported.

MR. CHARLES R. FELTON.* It is astonishing how closely you may predict from a population curve what the future population of a city will be, at least we have found it so in Brockton. We have had a curve plotted for several years, and have come remarkably close in our predictions on the last three censuses. Just prior to our last census the reporters, in attempting to forecast what it would show, interviewed me, and I simply referred to the chart and predicted a population of 48 000. After the first returns came in the reporters joked me a little on having missed it because I was 18 off. I said there must be some mistake, and our later returns gave us within 6 of my figure.

* City Engineer, Brockton, Mass.

ON THE PROTECTION OF PUBLIC WATER SUPPLIES FROM POLLUTION DURING THE CONSTRUCTION, MAINTENANCE, AND OPERATION OF RAILROADS, WITH SPECIAL REFERENCE TO THE WATER SUPPLY OF SEATTLE, WASHINGTON; TOGETHER WITH CRITICISMS OF THE PRESENT METHODS OF WATER SUPPLY AND SEWERAGE OF RAILWAY TRAINS.

BY WILLIAM T. SEDGWICK, PROFESSOR IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

[*Read September 14, 1906.*]

In an address before the New England Railroad Club, in Boston, in November, 1899, the author drew the attention of railway managers to the unsanitary and objectionable practice of allowing the droppings of the closets of passenger cars to be scattered all along the lines, polluting the trucks and roadbed, and to a greater or less extent the air, the soil, or water in the vicinity. Since that time other writers have touched on the same subject, but for one reason or another it has as yet received but little attention.

Railways, both steam and electric, in rapidly increasing numbers, have been constructed, maintained, and operated upon the collecting grounds, alongside the principal tributaries, and even over portions of the storage reservoirs, of numerous water supplies, without exciting more than occasional comment or protest. Suddenly and unexpectedly within the last few months the whole subject has been brought to the front by the proposed construction of a great transcontinental railway close alongside a mountain stream used without filtration or storage as the water supply of a large and rapidly growing American city, namely, the city of Seattle, Washington. The Chicago, Milwaukee & St. Paul Railway, in seeking entrance to Seattle, after having selected the Snoqualmie Pass as the proper place for crossing the lofty Cascade Mountains, found the best route from the pass to that city to be one which for 11 miles runs through the valley and very near the shores of

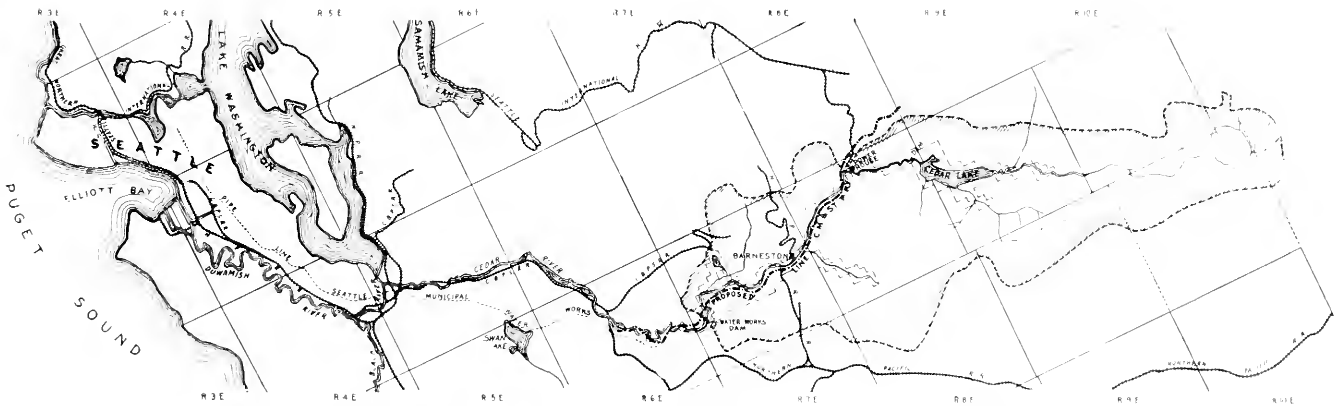


FIG. 1.—MAP SHOWING PROPOSED ROUTE OF CHICAGO, MILWAUKEE & ST. PAUL RAILWAY, THROUGH CEDAR RIVER WATERSHED. (SCALE ABOUT 8 MILES TO AN INCH.)

Cedar River, the source of the public water supply of Seattle, as shown on the map, Fig. 1. Much of the land bordering Cedar River is owned by the city of Seattle, having been purchased under the advice of its able and intelligent city engineer, Mr. R. H. Thomson, for the express purpose of protecting the watershed. Hence it became necessary for the railroad to obtain from the city a right of way over this land. This was arranged to be done by means of an ordinance requiring the mayor to sign deeds for such a right of way 100 feet wide and 11 miles long through the watershed and for most of the way very near the river. Such an ordinance was accordingly drawn up, passed by the city council on May 21, and approved by the mayor on June 5 of the present year (1906).

This ordinance marks the beginning of a new epoch in the relation of railways to public water supplies, and hence deserves thorough and careful consideration. As far as I am aware, it is the first example on record of the frank recognition of the dangers involved in the construction, maintenance, and operation of a railway along the shores of a public water supply, together with explicit and extensive provisions for meeting them. I make no apology, therefore, for quoting from it at length. It is entitled:

" ORDINANCE NO. 13 836.

" An ordinance granting to the Chicago, Milwaukee & St. Paul Railway Company of Washington, its successors and assigns, a right of way one hundred (100) feet in width for the location, construction, maintenance, and operation of a railroad across and through lands owned by the city of Seattle, in the county of King, state of Washington, and authorizing the execution and delivery of a conveyance of such right of way. Be it ordained by the city of Seattle as follows:

" SECTION 1. That there be, and hereby is, granted to the Chicago, Milwaukee & St. Paul Railway Company of Washington, its successors and assigns, a right of way, in perpetuity, for the location, construction, maintenance, and operation of a railroad upon, across, and through the lands owned by the city of Seattle, in the county of King, state of Washington, one hundred (100) feet in width, being fifty (50) feet of such width on each side of the center line of the railroad of said company as located and staked out upon the ground, which lands are described as follows, to wit: . . .

"Provided, however, that nothing in this ordinance contained shall be construed to grant any right to said railway company, its successors or assigns, to occupy or use the bed of the stream of Cedar River, or any portion thereof, or any of its tributaries, except so far as herein authorized for the purpose of constructing and maintaining bridges across said river or for the purpose of constructing and maintaining embankments for the roadbed of said railroad.

"SECT. 2. The grant of the right of way herein contained is upon and subject to the following conditions, to wit:

"1. Said grantee shall begin the construction of its railroad upon the right of way herein granted within one (1) year.. . . .

"2. No station shall be established or maintained by said railway company, its successors or assigns, between the city intake and the easterly terminus of the right of way herein granted without the consent of the city of Seattle first having been granted by ordinance.

"3. While the said right of way is being cleared and prepared, and during the construction of said railroad thereon, the camps or living quarters of the men engaged in such work, and the accommodations for any animals employed thereon, shall be located and maintained at such distance from said Cedar River, in good sanitary condition, as shall be approved by said city of Seattle.

"4. The grantee, its successors and assigns, shall locate the living quarters of any and all employees engaged in the care and maintenance of the railroad constructed upon the right of way herein granted, or in the operation and maintenance of any side or passing tracks, water tanks, telegraph or block signal stations or towers, or other appliances, constructed and maintained upon said right of way, at such distance from Cedar River as shall be approved by the city of Seattle, and shall maintain such living quarters in good sanitary condition.

"5. The said city of Seattle may employ an inspector to patrol or inspect the work of construction of the said railroad upon said right of way for the purpose of ascertaining whether said work is being prosecuted in accordance with the conditions herein contained, and said grantee agrees to pay the cost of such inspection."

Then follows a location of the bridges to be built, with a provision at the end as follows:

"All bridges constructed upon said right of way across any creeks or streams intersecting said right of way shall be solid-decked structures, and all bridges, trestles, and approaches shall be constructed and maintained so as to prevent any foreign matter

from dropping from engines, cars, or trains passing over the same into Cedar River or into the creek or streams running into said river.

"7. Said grantee, its successors and assigns, shall not, during the construction of said railroad, or thereafter in the maintenance or operation thereof, place, throw or deposit, or permit the placing, throwing, or depositing in said Cedar River, or in any creeks or streams running into said river, or upon any ground adjacent to said river, any offensive or deleterious matter which may cause the pollution of the waters of said streams, and said grantee, its successors and assigns, shall at all times maintain the right of way herein granted, and the railroad constructed thereon, in such manner as not to cause any pollution to said stream."

Further on is a section in which it is provided that if the railroad, in order to avoid curves of more than 3 degrees, finds it necessary to go into the river,—

"Embankments required for the proper support of said roadbed may be extended into the bed of the stream, provided that such embankments shall be built of such material and in such manner as to avoid pollution of the waters of said river, and so as to prevent the escape or passage of offensive matter from or over said embankments into the said river."

Finally, there is a section not only authorizing the mayor and comptroller, but directing them, "upon the taking effect of this ordinance, to execute and deliver to said grantee a deed conveying in perpetuity . . . the right of way herein granted . . . for the construction, maintenance, and operation of said railroad. . . ."

The ordinance was passed by the city council on May 21, 1906, and approved by the mayor on June 5. It thereupon became incumbent upon the mayor to issue the deeds by which the railroad should acquire the right of way, and it was supposed that such deeds would issue without delay. Up to this time there had been no open opposition to the plan, the ordinance having been prepared by the legal representatives of the railroad company and the city officials, acting together. I am assured by the railroad officials that it was their intention to protect the water supply in every possible way, and that they believed they had fully and adequately done so by the provisions contained in the ordinance.

Not long after the mayor had signed the ordinance, but before he had signed any of the deeds contemplated under it, an agitation arose in the city, alleging that the water supply, instead of being safeguarded by the ordinance, was in reality seriously endangered by it, inasmuch as the building of the railway must of necessity bring into the valley hundreds of laborers of an uncleanly type, who would inevitably pollute the river, while its maintenance and operation necessarily involved the temporary or permanent presence in the watershed of section hands, signal men, trainmen, wrecking gangs, and others, not to mention the thousands of passengers who would annually travel on the road and use the car closets, spit from the car windows, or otherwise contaminate the watershed.

This agitation rapidly grew to large proportions, being participated in by physicians, labor organizations, women's clubs, the Chamber of Commerce, good government clubs, and other public bodies, and before long culminated in an order issued by court on application of the King County Medical Society, composed of physicians in Seattle and vicinity, restraining the mayor from signing the deeds. I am informed that the legal representatives of the railroad, who supposed that they had amply and even generously provided for the protection of the water supply, were nonplussed at this sudden outbreak of popular feeling, and unable to understand why it had arisen, or why it should have reached such proportions. Of the reality or extent of the objections there was, however, no doubt, and in self-defense against the popular storm the authorities of the railroad secured the services of several experts to investigate the subject and report to them upon the question whether the railroad could or could not be built, maintained, and operated in Cedar Valley, as proposed under the ordinance, without endangering the purity of the public water supply of Seattle. These included Mr. J. W. Alvord, civil engineer, a member of this Association; Professor Pammel, of the Iowa State University; Professor Bissell, of the Mechanical Engineering Department of the same institution; Prof. E. G. Smith, of Beloit College, and afterward the writer. Mr. Alvord, Professor Pammel, and Professor Bissell in due time made their reports, and a brief summary of Mr. Alvord's report

appeared in the *Engineering News*, page 238, August 30, 1906; the complete report follows as an appendix (A), page 442, to this paper. These reports threw much light on the situation but did not appear to the citizens to settle the question, and hence did not calm the popular storm.

The citizens of Seattle had long supposed that in Cedar River they possessed a perfect water supply, for Cedar River is a beautiful stream, running through a virtually uninhabited district, and forming the outlet of Cedar Lake, a large sheet of water lying, remote and almost inaccessible, 1 500 feet above the city in the Cascade Mountains. It is surrounded by mountains rising several thousand feet about it, — a lake probably as beautiful as is Lake George. When, therefore, Mr. Alvord showed that there were a number of logging camps on the watershed with very defective sanitary appliances, practically draining directly into the stream or its tributaries; when he further showed that the sawmill camp of Barneston, having about one hundred and twenty people, partly Asiatics, connected with it, was virtually draining into the stream, and that similar nuisances existed elsewhere on the watershed, the people of Seattle were surprised and greatly annoyed. The conclusion of Messrs. Alvord, Pammel, and Bissell, briefly stated, was that the water supply was already far from perfect, that the railroad could be safely built through the valley, and that it would not be as much endangered by the coming of the railroad as it was already endangered by existing nuisances.

Professor Smith arrived on the ground somewhat later than Mr. Alvord, Professor Pammel, and Professor Bissell, and proceeded to make his own investigations. The author arrived later still, but even before he had come the physicians and other objectors to the ordinance had expressed their readiness to accept as final the opinion of any one whom they considered as an unprejudiced expert, or of any group of such experts, regarding the question at issue. After considerable discussion and delay it was agreed on all sides to leave the settlement of the matter to a commission consisting of Dr. A. C. Abbott, Professor of Hygiene in the University of Pennsylvania and health officer of the city of Philadelphia, on behalf of the city of Seattle; Dr. Charles Harrington, Professor of Hygiene in Harvard University, and secretary of the State

Board of Health of Massachusetts, on behalf of the King County Medical Society; and the writer, on behalf of the railway company. Meantime, Mr. John R. Freeman, the eminent hydraulic and sanitary engineer, who fortunately happened to be passing through Seattle on his way to Alaska, was prevailed upon to visit the watershed with some of the other experts and to make a special report on the subject to the State Board of Health of Washington which, through its energetic and able secretary, Dr. E. C. Heg, had already taken an active interest in the problem and had instructed its engineer, Prof. W. J. Roberts, of Pullman, Wash., to make an independent investigation.

As a matter of record and for convenience of reference, the report of the commissioners, Mr. Alvord's report, and Mr. Freeman's report are printed as appendixes to this paper, and since these cover completely and in detail all the points at issue I need not here dwell further upon these. There still remain, however, certain other important aspects of the relation of railroads to water supplies which deserve our careful consideration.

THE WATER SUPPLY AND SEWERAGE OF RAILWAY TRAINS.

As I have already said, as long ago as 1899 I urged the members of the New England Railroad Club to devise some better methods of disposing of excrements than those now customary on railroad trains. I dwelt also at much length upon the need of improved water-supply arrangements — a subject which still deserves the closest attention. Through cars are often run great distances, passing through various cities and towns en route, and receiving from time to time fresh supplies of water. It may, therefore, easily happen that if any one of these supplies is impure, the water tanks shall become contaminated, and persons traveling in the car, or even joining it at stations which have excellent water supplies, may be exposed to the danger of contracting disease. I have myself had offered to me in a dining car in New England a clayey water which had obviously been taken into the water tanks on the previous day when the water supply of the car had been replenished in Washington, D. C. To a very much less extent travelers may be exposed to similar dangers from contaminated ice.

The importance of the distribution of contaminated water

from large centers such as Chicago, Cleveland, Pittsburg, and Washington, having now or having recently had polluted water supplies, is very great, and well deserves the keenest attention of epidemiologists, especially of those who have been puzzled to explain the excess of typhoid fever in the United States over that in other civilized countries, such as England and Germany. At the same time the railroad companies can hardly be blamed for filling their water tanks from any accessible water supplies which are locally deemed good enough for the use of the public.

There still remains, moreover, a feature of the method used for water supply within the cars themselves which calls for serious criticism, and that is the use of the common drinking cup which here, as always, is a well-known sanitary abomination. A dozen or more years ago it was the almost universal custom on American railways for one of the brakemen to carry through the cars a tin can to which were attached a couple of removable cups or glasses. These were used in turn by thirsty passengers who remained in their seats, the glasses being filled for them by the brakeman as he paused for the purpose. This practice is now largely done away, and in its place a single cup or glass is kept under a fixed water tank, from which a jet of water can readily be drawn into the cup or tumbler, which is thus intended to serve the wants of the population of an entire car. Any one who thinks that this plan of meeting the water-supply needs of a large number of people of all sorts is either attractive or wholesome, has only to sit near the water tank of a crowded excursion train on some hot summer day, especially if the car is filled with mothers and young children, in order to be quickly convinced that a reform is here urgently demanded. Few things are more trying to a sanitarian than to observe a series of thirsty passengers of all degrees of cleanness and uncleanness applying their lips in succession to one and the same tumbler which is seldom, if ever, even rinsed between times. Wholly apart from the question of the quality of the water furnished, the opportunity here provided for the exchange of disease germs must be apparent to any one, and I need not further enlarge upon this custom, which is both familiar and disgusting.

A remedy might easily be found by having the faucet of the water tank bent upward and provided with a special orifice so

that a small jet should rise for an inch or so above its tip, thereby furnishing a "sanitary fountain" similar to those which, in increasing numbers, are being provided in parks, playgrounds, gymnasia, schools, and other places where many persons must, of necessity, drink from a common supply. Travelers should also be encouraged to bring with them on railways their own private drinking cups.

Criticisms have frequently been made of the filling of the water tanks and the handling of broken pieces of ice for the tanks by employees whose hands are far from clean, and it must be admitted that the whole matter of the water supply and ice supply of passenger trains frequently leaves much to be desired in the way of sanitary improvement.

As for the sewerage of trains, within a few years, and from motives of mere decency, the custom has become general of locking the closets for the purpose of excluding passengers from them on trains approaching or standing at important stations, a practice which, as will be explained beyond, while certainly contributing to the cleanness of the station platforms, is decidedly objectionable on hygienic grounds. Only in very rare cases, however, so far as I am aware, are the closets of the numerous passenger trains on a great trunk line kept locked for several miles while approaching and after leaving a station, not for decency's sake but in order to protect a public water supply.

Near the city of New Haven, Conn., many travelers have noticed that the closets on the Pullman and other cars going east are kept locked after leaving that city until Branford, nine miles away, has been passed. Going west, the closets are locked as the trains approach Branford and are not unlocked until after leaving the New Haven station. I am informed that the reason for this practice is that some two or three years ago inspectors employed by the New Haven Water Company, while patrolling the Lake Saltonstall watershed near Branford, observed and reported upon the presence of fecal matter on the rails or roadbed, very near the intake of the Lake Saltonstall supply of the water company, which company thereupon complained to the railway officials, who issued an order requiring all closets to be kept locked on trains traveling between Branford and New Haven. I am

also informed that a similar rule requires the locking of all closets on trains on the Northampton Division of the same road between New Haven and Cheshire, a distance of fifteen and one-half miles, for the better protection of another supply of the New Haven Water Company, the Lake Whitney supply.

I have been unable, however, to find that any similar precautions are taken in regard to freight trainmen. On the contrary, inquiries have shown that on our eastern railroads the freight brakemen and trainmen have to get along the best way they can in answering the calls of nature. I am told that in the West there is generally a closet in the caboose for the use of these men, but that near Boston the crews of freight trains either make use of empty box cars, which they defile at their convenience or necessity, or of the coal pile in the tender; or that, when taken hurriedly, they even use as a seat the couplings or bars connecting the cars — obviously an uncomfortable and dangerous practice, especially when the train is moving rapidly. All of these facts further illustrate the crudity and primitive character of the sanitary arrangements of our American railway trains, for, obviously, no occasional locking of closets on passenger trains will ever be more than a partial and very superficial remedy of the present crying evils.

The New Haven case is the only one of which I have heard in which definite fecal pollution of the rails was observed near a water supply, or in which any similar observation led to an immediate attempt at reform. I have recently learned, however, from Mr. R. W. Pratt, chief engineer of the State Board of Health of Ohio, of a case, not exactly identical with the New Haven case, but so nearly in the same category that I have asked him to give me a statement of it, which he has kindly done, and which he permits me to quote here:

"The village of Plymouth, Ohio, has, until recently, used as a partial source of water supply a small tributary of the Huron River. Water was taken at a point a short distance southeast of the village, immediately north of, and very near, the Northern Ohio Railroad bridge, which spans this tributary stream or creek. Two hundred feet west of the creek, and twenty or thirty feet above it, adjacent to the railroad, is a water tank used for railroad pur-

poses. A small gully runs from the tank to the stream, which it enters just above the intake.

"In June, 1905, during an inspection of the public water supply by a representative of the Ohio State Board of Health, an east-bound train, composed of freight cars, cattle cars, and one passenger coach, stopped at the tank to take water. After filling the locomotive tender, the train slowly passed on to such a point that the forward cattle car was brought directly opposite the tank. The day being hot, the animals were badly in need of water. In order to water them, a brakeman swung the spout of the water tank directly into the car, turned on the water and signaled for the locomotive to move slowly forward. By this procedure the cattle and hogs in the several cars were given a generous shower bath, while much of the accumulated filth in the bottom of the cars was flushed out into the gully by the side of the track, through which it flowed rapidly down to the creek, quickly entering the latter at a point not more than fifty feet above the intake of the Plymouth water supply.

"Inquiry showed that this was a common practice on the part of the railroad men during warm weather. It should be added, however, that the railroad officials, when the matter was brought to their attention, agreed to see that the practice was discontinued; and that the village has recently taken steps to procure a sufficient water supply from other sources, so that the use of the creek water will not be necessary in the future."

This case seems to me to be a very important contribution to the literature on this subject, which at best is but scanty, for I may say parenthetically that I have examined English and German authorities and have found nothing of any consequence in them on this subject. One would, perhaps, not expect to find much in such works, because foreigners, as a rule, use closets at stations, leaving the trains when necessary for that purpose. It is, generally speaking, only on the fastest trains that closets are provided, and from a German work on railway hygiene, published in 1904, it appears that the discharge pipes from the closets of German express trains discharge their droppings upon the roadbed precisely as ours do.

Finally, quite apart from the matter of sewage disposal, let us consider briefly the hygienic aspect of locked closets on railways. In the first place, although it is true that our commission recommended the locking of the closets while trains were going through

the Seattle watershed, we did not depend upon such locking as an entire safeguard, and I do not believe that locking ever will be a complete safeguard. There are times when people are ill, when they simply *must* get access to the closets. There are times when persons so imperatively require to get into the closets that they will tip the porter heavily, or do almost anything, in order to obtain admittance. And they ought to obtain entrance. It is a hardship, and worse, not to allow access to the closets, the locking of which must be pronounced, once and for all, an imperfect, crude, and, not infrequently, an absolutely barbarous device. The practice is rude and unhygienic, even in its least objectionable form of locking the closets only while the train halts at stations. For any longer period, as for example, while trains are covering the distance from New Haven to Cheshire or New Haven to Branford or *vice versa*, it is much worse.

Moreover, the practice is not only barbarous and unhygienic, it is often ineffective. How is anybody going to be driven out of a closet at the right time if he is already in it before the train arrives at New Haven going east, or at Branford going west? I have myself, while observing the actual working of this regulation, been informed by a porter as we passed by the New Haven intake near Branford that he could not lock a closet as " there is somebody in it." The regulation is clearly ineffective and unworthy of modern industrial organization. It must be done away with, and that at the earliest possible moment.

As to the dropping of the excreta through the discharge pipe upon the roadbed, this, also, is a crude, unsatisfactory, and unsanitary way of disposing of excreta on trains. At best it necessarily soils the track and the trucks, for the section hands and others to walk or to work upon; it sometimes endangers public supplies of water; it always pollutes the air, and under some circumstances, by being carried by section laborers or others on their hands to their homes, endangers persons not immediately in contact with the roadbed or rolling stock.

But, it will be asked, what can be done about the matter? The answer is that the time has come when we must insist that if a railroad company finds it practicable to carry large iron tanks under passenger cars for gas or for refrigerator purposes, it can and must

also carry there an iron tank for sewage. If for any reason this is impracticable, earth closets with pails frequently changed may be used. Railroads must somehow cease distributing fecal and urinary matters all along their lines. The closets ought not to be shut up, either at stations or anywhere else, so that the all-important personal hygienic requirements are defeated. The sewage tanks or pails could be emptied at selected places, either at the end of the run or, on long runs, at principal stations, precisely as water and gas are now taken into special tanks at principal stations. Of course there would have to be disinfection from time to time, and some trouble would have to be taken to see that the sewage tanks were kept clean and free from smells, but this could be done and ought to be done. At any rate, something different from the present crude, disgusting, and dangerous practice must be devised. And, where railroads run over or very near water supplies, as they often do and often must, if common decency and the comfort of the men are not enough to secure it, some provision must also be required for the convenience of freight trainmen. Upon wrecking trains and repair trains it would be easy enough to carry a portable closet, or a fixed privy with earth closet beneath, so that all excrements should later be carried off from the watershed and deposited at a distance.

I am aware, of course, that tanks underneath the cars would, in winter, be exposed to freezing, and that special pains would have to be taken to prevent this. It will not be as easy, certainly, to get rid of the excreta in a decent and scientific way, as it is simply to let them drop down through a hole in the floor; but we have got through dropping excreta in that way in our houses and hotels, and we must stop doing it in our traveling houses or hotels, that is, in our passenger cars. Water-works authorities, especially, must insist that whenever a railroad passes over a watershed it shall be subject to regulations regarding the discharge of excreta not less stringent than those which would be applied to an hotel or other place of public resort situated on the same watershed.

(As this paper is passing through the press, my attention is drawn to a newspaper statement touching another aspect of the sanitation of railway trains, namely, their garbage disposal:

"It was a surprise to me last week to see, just below the picturesque stone bridge which crosses the main street of —, a trap for maladies of some sort, if not for typhoid. On the narrow roadbed, and almost covering the railway tracks, were strewn refuse of all kinds, soiled papers, fragments of cooking — in short, all the débris of human life that makes excellent food for pigs, with streams of dirty water forming pools that might sink into the soil eventually, but at present were stagnant. The spectacle gave me a jolt. It was so foreign to the general impression one receives of prosperous — above ground, and it was wondered how such a garbage hole could ever be overlooked by the powers that be. No doubt this blot on the railroad banks has escaped the management's eagle eye."

Doubtless some of the employees upon dining cars and other departments of railway service look upon railways very much as some Americans look upon their streets, namely, as being practically waste baskets, garbage pails, and sewers. In all these matters our people are generally uneducated and careless. In the city of Boston the police commissioner has lately set a commendable example by ordering the arrest of all persons misusing the public ways in the manner just described, and a similar solicitude for the sanitary care of our railways on the part of railroad officials would doubtless effect a corresponding reform.)

APPENDIX A.

Report to the Chicago, Milwaukee & St. Paul Railway Company of Washington, upon the Sanitary Situation Created by the Proposed Construction, Maintenance, and Operation of its Line through a Portion of the Collecting Grounds of the Public Water Supply of the City of Seattle.

BY JOHN W. ALVORD, CONSULTING ENGINEER.

At your request I have examined a large portion of the Cedar River watershed, the projected line of your railway, and the sanitary situation occasioned by its construction and operation. For this purpose, in company with Professor Bissell and Professor Pammel, of Ames, Ia., a week was spent in an examination of the territory in question.

During this trip we were accompanied by the division engineer of your company, Mr. Wilson, who pointed out the proposed location of the track from the company's plans and profiles. On Monday, the 16th of July, we entered the watershed by way of North Bend, examined the sanitary situation at the city's power house, and from thence drove up to the outlet of Cedar Lake, examining its shores in the vicinity of the outlet and at the outlet works in general. We then returned to the power house and commenced a detailed examination of the located line of your railroad from the power house to the city intake, measuring at frequent intervals the distances of the center line of the right of way from the water's edge, noting the soil conditions and other data. That portion of the line between the power house and Barneston is quite accessible for examination and was easily covered in the afternoon of the 16th.

DIFFICULT TO TRAVERSE.

We spent the night of the 16th at Barneston, and the next morning continued down the line of the right-of-way from Barneston to the city's intake. This portion of the line is inaccessible

and difficult, the surveyors' line passing through heavy timber and dense underbrush and over many fallen logs and other impediments. The night of the 17th we spent at Ravensdale, and on the morning of the 18th took horses for Kangley, noting soil conditions, habitations and other data at that point, and the terminus of an interesting creek which lost itself in the porous soil just west of that station. We spent the night of the 18th at Barneston.

On the 19th we proceeded afoot by forest trail to the line of the Columbia & Puget Sound Railway, near Weyerhauser's logging camp No. 4. From there we proceeded to the Denny-Clay Company's works, the logging camps in the immediate vicinity, and the settlement at Sherwood. We continued from there to Walsh Lake and returned to Barneston that night. On the 20th we covered the territory drained by Taylor Creek, visiting Miller's logging camps Nos. 3, 5, and 6, also the intake and dam of the Barneston water supply on Taylor Creek and the shingle mill about a mile south of Barneston. On the 21st we noted the sanitary conditions around Barneston, and took the train for Seattle.

At the time the Seattle water works were first constructed I also visited this watershed in the interests of those who were expecting to take the bonds of the project, becoming fairly familiar with the topographic conditions of that section.

THE WATERSHED.

The watershed of the Cedar River above the intake appears to be one of the most extensive areas of porous soil utilized for natural filtration of a public water supply which it has ever been my fortune to observe. The glacial drift of which it is composed consists of coarse and fine gravels intermingled to a depth of some hundreds of feet. We looked in vain for traces of clays or finer soils. The surface mold is thin for the most part, and the level of the soil water on the benches and plateaus back from the river is evidently at a great distance below the surface, as indicated by the location of springs and the depth of the eroded streams. There is little or no surface run-off of the rainfall. Numerous potholes exist, depressions without visible outlet, and there was scarcely observed a dry run of any kind, or rivulet, save those of

running streams, few in number, which were marked upon our map.

The unusual porosity of the soil may be best illustrated by the statement that in passing over the located line of the railway, eleven miles along Cedar River, no run or rivulet or surface indication of wash of any kind was observed leading into the stream, which would indicate that the rainfall passed over the surface of the ground. We also observed that in passing over the Northern Pacific Railway, which crosses the watershed from north to south, no pains were taken by that company to ditch its tracks, to provide small culverts, or even, in the case of very considerable depressions, to arrange for the passage of water from one side of its embankment to the other. The soil, therefore, of this valley is a porous one, receiving the copious rainfall of this region and largely absorbing it, and by slow percolation filtering it to an unusual degree, thus creating the clear streams and exceptionally pure water.

POPULATION OF THE WATERSHED.

As nearly as our inquiries could determine, the population of this watershed is about 1,500 people, mostly employees of the various logging companies living in camps and concentrated at certain points along the small streams which are tributary to the Cedar River. This class of population is perhaps not the most desirable from a sanitary point of view, and their environment and situation, as we saw it, is not attractive. The camps are serving generous quantities of food to the men, much of which is wasted, and in order to dispose of this refuse in any considerable camp a dozen or more hogs are kept and fattened from the garbage of the camp. The hog pens invariably extend into the running stream, so that the hogs may water there at will.

We observed contamination of this character at Miller's Camp No. 5, situated on the north fork of Taylor Creek. This camp is working at the present time about 60 men. The liquid refuse of the kitchen is delivered immediately upon the bank of the creek, and the hog-pen is situated so that the hogs have direct access and were observed fouling the creek. The creek has a flow estimated at from $4\frac{1}{2}$ to $5\frac{1}{2}$ cubic feet a second, and is distant from the intake approximately $15\frac{3}{4}$ miles, measured along the flowing

streams. Such flow measurements as we made indicated that the rapidity of the stream was in no case less than a mile an hour, and often exceeded 2 miles an hour, the fall being very great.

LOGGERS POLLUTE THE WATER.

At Miller's Camp No. 3, working now about 15 or 18 men, there were two privies and a garbage pile in the immediate vicinity of the stream, so situated as to pollute the same. An old, abandoned camp in the northern part of section 30, township 22, range 8 east, showed traces of pollutions in the vicinity of Taylor Creek in the shape of carcass remains, garbage piles, and privies. This camp was about 400 feet from the stream, however, the ground sloping down to the creek.

Miller's Camp No. 6, working 65 men, is situated upon a side hill a considerable distance from running water, the water supply being pumped up from a spring some 2 000 feet lower down upon the slope. Pollutions at this camp, which were similar in all respects to the other camps observed, would, therefore, not be a sanitary menace. At Kangley there are habitations and a saw-mill, and the pollutions similar in all respects to the other camps observed were drained by a flowing brook running past the station. This stream pursues its course to a point about one-half mile below the station, and although flowing an amount of water estimated at 8 or 10 cubic feet per second, disappears entirely into the porous soil and sink-holes in that vicinity.

At Weyerhauser's Camp No. 4, situated on a stream flowing about 5 cubic feet per second and running into Rock Creek, there is a logging camp, with some 6 bunk-houses located immediately over the brook, and garbage piles and privies immediately adjacent to the same. Below the camp a hog pen, containing 15 hogs, was so situated that the stream was enclosed, creating conditions which were far from desirable. The distance from this source of pollution to the intake, measured along the line of the flowing stream, is $5\frac{3}{8}$ miles.

At the Denny Clay Company's works we were told that there were about 100 men at work and probably 500 people in the vicinity. There are perhaps 25 houses of all kinds, besides the company's plant, including a considerable camp, sewered into a small

rivulet flowing, at the time of our visit, perhaps $1\frac{1}{2}$ cubic feet per second, and draining into Webster Creek.

Proceeding down to Walsh Lake we found upon its banks a log-loading outfit immediately adjacent to the mouth of Webster Creek. We observed at this point that the loggers themselves were not in the habit of drinking the water from this brook, but obtained their drinking water from a spring some twenty-five minutes' walk up the railroad. Walsh Lake has fairly good shores, although considerable decaying timber is found about the lake, as is the case with all other lakes and streams in this country. Three habitations were observed on the opposite banks of the lake which appeared to be occupied. Each habitation was provided with barns, etc., which apparently drained into the lake. Persons were observed bathing on the opposite shore of the lake. A little farther south from the outlet of Webster Creek is another log-loading outfit, working about 50 men. The outlet of Walsh Lake, meeting the stream which flows by Weyerhauser's Camp No. 4, forms Rock Creek, and at the junction of these two streams is situated Weyerhauser's Camp No. 2, containing, we are told, 85 men. The camp is situated $4\frac{1}{2}$ miles above the city's intake, but owing to the lateness of the hour we were unable to visit this camp and obtain any data as to its sanitary condition.

POLLUTIONS AT BARNESTON.

The sawmill and camp at Barneston are situated upon an upper bench or bank, perhaps 600 to 700 feet distant from the edge of the river. The drainage of the benches at this point, if they may be said to drain at all upon the surface, is, generally speaking, away from the river, their elevation along the outer edge being higher than at a little distance back. While there is considerable pollution at Barneston and a large camp, it is probable that for the larger part it sinks into the soil and is well filtered before reaching the river. A considerable number of hogs and cattle, however, have free access to the water of Cedar River, and roam over the camp at will. Barneston is situated about $9\frac{3}{4}$ miles above the intake, measured along the line of the flowing streams.

Between Barneston and the power house the city of Seattle has constructed its pole line along the north bank of the river and

somewhat closely following the same. For the purpose of access to this pole line, and probably originally for construction purposes, there has been built a road which follows the bank of the river, in places coming within 25 feet of the water's edge, giving full and free access to the river for the whole of its distance. Fishermen were observed trout fishing; remains of dinners were observed at the water's edge. Not far below the power house a considerable number of cattle were pasturing, which have ready access to the water of the river. A number of log jams in the river were noticed, and a great deal of decaying wood lines the stream banks, which, while common to this part of the country, is not usually considered a desirable feature of a watershed for public water supply. The sanitary conditions at the power house and the habitations there could not be criticised.

CEDAR LAKE.

The outlet of Cedar Lake was viewed. The lake appears, in many respects, to be an ideal one for purposes of water supply, the banks being for the most part steep. Near the outlet an extensive swamp borders the lake, filled with decaying wood and teeming with aquatic life. The premises of the keeper of the inlet works appeared to be properly protected, although 6 head of sheep were observed grazing about the outlet and having free access to the river. Fishermen were observed in a boat upon the lake, and the excrement of cattle upon the banks of the outlet. At one point, about 20 feet from the water's edge, human excrement was observed and noted. It is apparent that, while the conditions at this point are not serious, reliance is had fully upon the wildness and inaccessibility of the spot rather than upon any sanitary control.

The river between Barneston and the intake runs through an exceedingly wild and inaccessible region, and is very difficult of access. At only two points in this reach does the railroad line approach closely to the river, and at places it is from 900 to 1 400 feet away. No serious pollutions of any kind were observed upon this section; just above the dam of the intake there appeared to be an undesirable swamp on one side of the stream.

SUMMARY OF OBSERVATIONS.

Speaking generally, our impression was that the city of Seattle has an exceptionally good watershed, consisting of forest-covered mountain slopes and highly permeable soil, which forms, in the lower part at least, a great natural filter; mountain brooks, spring-fed and of great natural purity, freedom from permanent population, and a copious rainfall. These advantageous natural conditions, however, have not been protected, possibly, by want of adequate legal powers, but certainly by lack of suitable sanitary supervision. Many portions of the district being virtually inaccessible, much serious pollution is permitted which is probably, for the most part, unknown to the authorities.

There are about 25 miles of railroad now existing in the watershed. A considerable portion of this mileage is logging roads owned by private companies. Nearly all of these roads were traversed by us during our examination, and in no case did we see anything which seemed to us dangerous or menacing from their presence. The real menace which we observed lay in the conduct and character of the camps which were located upon flowing streams.

PROPOSED RAILROAD LOCATION.

The Chicago, Milwaukee & St. Paul Railway is proposing to enter the Cedar River watershed at or near the present power house, and traverse the valley to the intake along a line for the most part south of the river.

Ordinarily the presence of a railroad track and trains within a watershed is not looked upon by sanitary authorities as a menace when properly regulated. It is through the population and industries created by railroads that sanitary difficulties occur. Pains have been taken to investigate a considerable number of watersheds in this country which draw their waters from surface supplies, unfiltered either by artificial or natural means, and it is found that an exceedingly small proportion of cities are able to make the claim that no railroads exist upon their watersheds. Indeed, the question, so far as can be ascertained, has never before been raised as to the menace of the actual track and trains.

Following are some of the more important cities in this country which derive their supplies from surface sources, with the approximate mileage and number of stations upon their watersheds:

City.	Population in 1900.	Source.	Approximate Mileage of Railroads and Number of Stations.
New York, N. Y.	3 350 000	Croton River	15 miles railroad, 18 stations.
Boston, Mass.	560 000	Nashua River, Sudbury, and Cochituate	31 miles.
Baltimore, Md.	508 000	Gunpowder River	38 miles parallel, 11 stations on map.
San Francisco, Cal.	342 000	Lake Merced, mountain streams	None.
Providence, R. I.	175 000	Pawtuxet River	10 miles, 10 stations.
Kansas City, Mo.	163 700	Missouri River	Over 300 miles in immediate vicinity.
St. Paul, Minn.	163 000	Small lakes	No railroad.
Rochester, N. Y.	162 000	Hemlock Lake	No railroad. Summer resort around lake.
Denver, Colo.	133 850	South Platte	75 miles, 11 stations.
Worcester, Mass.	118 400	Lynde Brook	No railroad.
New Haven, Conn.	108 000	Mill River	35 miles, 10 stations.
Fall River, Mass.	101 800	Watuppa Lake	5 miles, 3 stations.
Omaha, Neb.	110 000	Missouri River	210 miles below Sioux City, 12 stations.
Scranton, Pa.	102 000	Roaring Brook, Oak River	10 miles.
Cambridge, Mass.	92 000	Stony Brook	5 miles.
Grand Rapids, Mich.	87 500	Grand River	260 miles, 70 stations.
Richmond, Va.	85 000	James River	150 miles parallel, 92 stations.
Hartford, Conn.	80 000	(Brooks)	15 miles, 4 stations.
Trenton, N. J.	75 000	Delaware River	100 miles parallel.
Waterbury, Conn.	45 800	(Ponds)	No railroad.
Mobile, Ala.	38 400	Clear Creek	No railroad.

A very large majority of cities, therefore, have railways not only upon the watershed, but paralleling the streams from which their waters are taken, nor do the majority of such cities have excessive death-rate from zymotic disease, and, so far as I am aware, no criticism has ever been seriously raised that the presence, at least of the track and trains, in such cases constitutes a menace in any way. But there are sometimes not only practical reasons why precautions should be taken to insure the purity of water supplies, there are also esthetic reasons for guarding against contamination, and particularly in a case like the Cedar River, where preliminary arrangements are possible and where proximity to the flowing stream is close, it would seem wise that some precautions should be observed which would prevent the drainage from the track from directly entering the stream, or which would prevent those passing along the tracks from access to the stream in any way.

THE OPERATION PROBLEM.

The fact that a railroad will be constructed the entire length of the river from the power house to the intake, has advantages as well as disadvantages. It provides means of approach to the river at points where it is now inaccessible, but it also provides at the same time means for controlling the watershed and observing its condition, not only by the agents of the city, but by the observation of the general public as well, which means that public sentiment will by such means be created which will result in regulations, adequate police powers, and proper control. While, therefore, to some degree a railroad so located must of necessity increase access to the river valley, its presence is an efficient check on some forms of pollution which are now in progress and which have been undiscovered.

The precautions which would suggest themselves as desirable would be, first of all, at points where the track is in close proximity to the river, to so drain the roadbed from the cuts into the soil back of the fills that, if there is any possibility of surface wash, — a possibility of which I have seen no evidences so far, — it shall be carried back upon permeable soil to diked-in sink-holes, such as naturally abound all over this area, so that such drainage shall not directly

reach the river. The drainage from the outer edge of the track may be intercepted by slightly widening the fills and forming a gutter, the waters from which can be led back to the inside of the track in the same way.

FENCE ALONG THE RIVER.

Secondly, a strong barbed-wire fence of adequate height might be constructed between the track and the river. Such a fence will, in my opinion, aid to control the situation and render it much less liable for passers along the track to defile the river in any way, or camp thereon without great difficulty.

Such a fence should be constructed by the city between the power house and Barneston along the right-of-way of its pole line, which would aid in excluding passers-by. This wagon road carries with it all of the menace of an operating railroad, and what has been said in reference to the drainage and precautions to be observed on the track of the railroad will apply with equal force to the city's own highway.

Suitable notices should be posted at frequent intervals upon such fence warning people from crossing it, just as fences with such rules are constructed around the reservoirs within the city. It is probable, of course, that malicious or ill-disposed persons will not be entirely prevented from violating the regulations of the city, but such persons have at the present time ready access to the river and stand no chance of even being discovered or controlled.

COVERS FOR BRIDGES.

The proposition of flooring the bridges with tight floors would meet with approval, and if it was thought desirable, at such points as the track necessitates, high fences could be erected to prevent the throwing of refuse from car windows directly into the river. The closets of the passenger coaches could be locked while traversing the watershed, as is ordinarily done now in traversing equal or greater distances through large cities and in all depot grounds.

These precautions should satisfy the most captious critic as to the security of the supply from the presence of the trains and track, and it might be suggested that they are much more adequate than are the provisions which are taken to guard against the contamination

of the water in the city reservoirs within the city limits from thoughtless or ill-disposed persons.

THE CONSTRUCTION PROBLEM.

No great reservoir for a water supply is ever constructed without adequate sanitary precautions. In fact, in these days no great camp of men should ever be gathered together for any public work without adequate sanitary provisions. And it is, of course, evident that construction camps along the Cedar River for twelve to fifteen months, if uncontrolled, would create a situation far from desirable. To admit, however, that adequate sanitary control cannot properly and adequately meet the situation is to admit that we know little or nothing about sanitary control. The progress of sanitary science has been such in the last generation that we have come to a positive knowledge of new dangers which threaten the life and happiness of the general community, and with this knowledge has come also the knowledge of how to properly protect and guard against such dangers. The conduct of camps, the sanitary precautions to be taken in and about them, have been thoroughly studied, with the result that where intelligent authority has been permitted to exercise full sway, all dangers have been entirely eliminated.

RULES FOR CONSTRUCTION.

The precautions that should be taken in the construction of the railroad in Cedar valley would be primarily as follows:

First, the full and complete authority of a competent and educated sanitary officer, with suitable assistance.

Second, the provision for proper location of camps safely away from the vicinity of the river.

Third, care of the camps, so far as the health of the men is concerned, and provision for the purity of their drinking water and food supplies.

Fourth, the provision for suitable conveniences for the men at or near their work.

Fifth, the removal and destruction of human excrement.

Sixth, the removal and destruction of garbage and kitchen waste.

Seventh, the care of draft animals, collection of their droppings and its destruction.

Eighth, provision for bathing purposes.

SANITARY AUTHORITY.

Absolute and autocratic authority should be vested in the sanitary officer in charge of the district to formulate such rules and regulations as seem to him necessary for the control of the camps and of the men. It would be proposed as one of the most important of these rules that all actual access to the river be barred; that the wire fences before mentioned, separating the track from the river, be constructed at the earliest possible moment; such special arrangements should be made as will obviate all necessity or desire on the part of the men to visit the stream for any purpose whatever. Such men as refuse to conform to the regulations or show themselves indifferent to their importance, or wilfully disobedient, should be promptly ejected from the camps, and a strong authority should impress upon the working force the fact that sanitation requirements are the first consideration.

All sanitary authorities agree that the best disinfectant for all forms of human waste is fire. This is the safest and easiest method to adopt in a rough country such as we are considering, where fuel is plentiful. Suitable latrines should be built at very frequent intervals along the line of work. An inexpensive crematory can be easily excavated in the bank, consisting of a rough grating immediately over a fireplace, upon which the garbage and refuse can be burned, as well as the excremental matters. Collections in large camps should be made frequently, and in the outlying and more remote latrines at least twice each twenty-four hours.

Garbage and kitchen waste of the camps should be burned along with the excremental matters. Frequent collections should be made, and no such refuse should be allowed to stand, under any circumstances, many hours. The liquid waste from the cook houses should be led in drains to some safe point where a sufficient area of subsoil can be uncovered so that filtration will be effectually permitted.

Suitable provision should be made around all of the cook houses to prevent the ingress and egress of flies which might tend to contaminate the food.

LOCATION OF CAMPS.

Camps should be placed at distances at least 500 or 600 feet from the river, on land preferably level, or draining very slightly.

if at all. Camps should be provided with a water supply, preferably from springs in the locality, or, if springs are not available, by water pumped up from the river in sufficient quantities for all purposes. It will be exceedingly desirable if the water supply of the camps can be placed under pressure, and suitable shower baths maintained for the use of the laborers, so that there is no desire as well as no opportunity or excuse for them to visit the river for any purpose. A physician should, of course, be provided, who shall watch the health of the men closely and carefully, and any case of sickness from any zymotic or intestinal disorder should be promptly removed from the watershed and all possible contamination carefully disinfected. Liberal quantities of disinfectants should be provided at every camp for the use of sanitary officers, and used under their directions.

SANITARY CONTROL OF CAMPS.

Men should be provided whose business it is to constantly keep the surroundings of the camps in a clean and presentable condition. All litter should be removed daily and burned, if possible.

Cleanliness in the bunk houses should be insisted upon. Personal cleanliness should be enforced, and persistently unclean employees should be debarred from the work.

Droppings from draft animals should be collected and burned in the same manner as human excrement. Draft animals should not be permitted to approach any stream entering the river, and always kept under full control.

IN GENERAL.

With these precautions properly taken there can be no question that all dangers of pollution to the water supply would be obviated, and that the water supply itself may be entirely above suspicion during all the time of construction. This statement is based upon the well-known efficacy of such regulations in the construction of great reservoirs, aqueducts, water supplies, even where such construction was proceeding above intakes already existing. It is also borne out by the experience of cities which purify their sewage and prevent contamination upon rivers, and it is substantiated by experience with military camps and military hygiene.

The history of the military camps has shown an increasing ability to control infection under most unfavorable conditions, and while our own volunteer army medical men did not during the Cuban War succeed so effectually as might have been hoped, they nevertheless learned a bitter lesson of the importance of such matters. Investigations of the conduct of the camps disclosed that important sanitary precautions had been entirely neglected. The typhoid which prevailed in the camps of the American army during the Cuban War is now attributed largely to the pollution effected by flies, which transferred objectionable matter from the latrines to the cook houses. And the lessons which were learned from that experience have been adopted by armies in all parts of the world so effectually that in the recent war between Japan and Russia the Japanese were practically enabled to completely annihilate this troublesome disease, as well as to reduce disease in general to the negligible minimum.

It may be remarked that the powers of a private corporation, backed by ample means and accustomed to secure efficient and capable service, unhampered by political influence or cumbersome checks, present an ideal instrument to carry out thorough and efficient sanitary control under proper supervision. So far as I can understand the situation, the interests of the railroad and the city are identical in considering this problem. Neither one nor the other can afford or should desire to trifle with matters pertaining to the public health. The attitude of both should be that of coöperation and diligence in seeking proper solution and acting on the best knowledge obtainable.

In conclusion, I believe that it is possible to construct a railroad in the Cedar River valley in a safe and sanitary manner, without a doubt. I believe, also, that once constructed, such a road, if operated without stations, with floored bridges and locked water closets, and with suitable fencing along the right-of-way, will present no opportunity for accidental contamination so great as exists at the present time. The presence of such additional men as it may bring into the water-shed, due to its operation, will be, in my opinion, offset by the increased facility which it will give for patrolling the entire length of Cedar River, and for affording the authorities and the public an opportunity to observe the

conditions of its source of supply. Dangers which might occur through careless control of the sanitary conditions of the construction forces can be met with proper diligence and intelligent supervision.

It would be quite idle to ask any physician in these enlightened days if he was able to enter a home where typhoid fever existed and successfully cope with the disease in such a manner that no danger to himself or other members of the family could ensue from infection. No reputable medical man would allow for a moment his inability to fully control the situation by suitable precautions founded on long experience and careful study.

The sanitary engineer is dealing with the same problem in a broader way; he is equipped with the same sort of information, the same sort of experience, and the same results of study, which enable him with certainty to control watersheds, water supplies, construction camps, and general conditions which make for the public health. And when authority and intelligence, combined with ample backing, are provided, this successful result has invariably been fully accomplished, just as the domestic problem of typhoid has been put under control.

CONCLUSIONS.

1. That in the Cedar River watershed the city of Seattle possesses a magnificent source of water supply.

2. That the city is not now and has not in the last few years properly protected this area from gross pollutions now existent.

3. That a virgin forest or inaccessible country does not afford ideal protection from pollution, but, on the contrary, a district easily accessible in every part and open to the publicity of frequent inspections and control offers the greatest degree of protection.

4. It is the settled policy, therefore, of most sanitary control of watersheds, while preventing as far as possible the growth of population and the incidental pollution therefrom, to open watersheds freely to the public observation, by creating means of access which facilitate inspection.

5. Railroads, so far as the track and trains are concerned, when properly regulated, are not regarded as a menace to the purity of surface waters by sanitary authorities.

6. It is through population and industries created by railroads that sanitary difficulties occur.

7. The 25 miles or so of railway now existing in the Cedar River watershed are in themselves no menace to the valley, but the logging camps which they serve are so conducted as to be serious pollutions in many cases.

8. That the operation of a completed railway line by the Chicago, Milwaukee & St. Paul Railway Company on or near the present location can be made entirely safe by some simple precautions, such as fencing, drainage, closed bridge floors and locked water-closets.

9. That care should be exercised during the period of construction of the railroad to prevent all access to the water by men or animals. For this purpose the river front should be entirely fenced off, policed, and, where necessary, water should be pumped up to the camps from the river under pressure, and in suitable quantities, for all purposes, including bathing and watering animals.

10. That efficient sanitary control should be had over all camps, cleanliness enforced, refuse of all kinds promptly collected and burned, drainage filtered and commodious and convenient sanitary arrangements provided, and strict control and authority maintained.

11. That the city of Seattle should also fence in the road which it has constructed along the river bank between Barneston and the power house, so as to prevent access therefrom to the river.

12. That the city of Seattle should regulate and control by intelligent sanitary rules the various logging camps now existing upon the watershed.

13. That it would be highly desirable to prevent decaying wood and vegetable matter from defacing the shores of Cedar River and its important tributaries, and to cut off the swamps at the outlet of Cedar Lake and immediately above the intake.

All of which is respectfully submitted.

JOHN W. ALVORD,
Consulting Engineer.

JULY, 1906.

APPENDIX B.

REPORT BY PROFS. A. C. ABBOTT, M.D.; CHARLES HARRINGTON, M.D.; AND WILLIAM T. SEDGWICK, PH.D., — A COMMISSION OF SANITARY EXPERTS,—TO THE CITY OF SEATTLE, THE KING COUNTY MEDICAL SOCIETY, AND THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY, ALL OF THE STATE OF WASHINGTON, UPON THE POSSIBILITY OF THE CONSTRUCTION, MAINTENANCE, AND OPERATION OF A RAILROAD WITHIN A PORTION OF THE WATER-SHED SUPPLYING DRINKING WATER TO THE CITY OF SEATTLE, WITHOUT DANGER TO ITS INHABITANTS.

We have been asked to answer two questions: *First*, whether it is possible to construct a railroad within the watershed of Cedar River, between the water intake and the power house, without danger to the character and wholesomeness of the water supply of Seattle; and, *second*, whether, in the event of such construction, the road can be operated without endangering the public health of said city through pollution of the stream.

In order to acquire personal knowledge of all the relevant conditions obtaining in and about Cedar Valley, and thus to be able to submit replies based upon something more than general principles and *a priori* reasoning, we have made a careful examination of the area involved, paying particular attention to the configuration of the ground and to the nature of the soil, and we have extended our observations so as to include that part of the watershed between the point where the proposed road leaves it to enter the Snoqualmie watershed and the borders of Cedar Lake. The proposed location of the railroad, as indicated by stakes, has been followed practically from end to end, and the adjacent strips have been examined at such points and to such an extent as seemed desirable or necessary.

We have also carefully examined and considered the various statements and arguments submitted to us.

In view of all the facts, we have no hesitation in answering both questions in the affirmative.

The main question involved in both propositions is whether pollution of the surface of the proposed right-of-way and of the vicinity by the wastes of the human body can be prevented; and, if it cannot wholly be prevented, whether contamination of the river can be guarded against.

It is a well-established fact that sewage matters containing myriads of disease germs can be rendered quite innocuous by filtration through gravel and sand, so that, within a short time, and at a distance of but a few feet, the effluent water may have an entirely different character and yield only mineral evidence of its former bad qualities. This fact was the main reason for careful scrutiny of the nature of the soil.

It appears that, along much of the proposed location, gravel and sand are not to be found. The forest floor appears to be reasonably thick, but at most points it consists almost wholly of combustible matter, and where fires have occurred the soil is shown to be chiefly loose rock, with neither sand nor gravel, and consequently not porous and suitable for effective filtration. At some points along the route, clay and silt deposits are evident, but these materials are not suitable filtering media, for they do not permit percolation. In view of these facts, special provision will be necessary for proper disposal of such waste matters as may find their way to the surface of the ground within and near the limits of the right-of-way during construction and operation of the road; for without such provisions the said wastes would inevitably be washed into the river in times of heavy rainfall, and, in the event of their containing pathogenic organisms, might lead to disastrous outbreaks of infective disease. The fact is, however, that the character of the water can be adequately safeguarded by the adoption of methods which will be described in detail further on.

The safeguarding of the water supply during the construction of the proposed road is by no means a simple matter, for construction involves the introduction of large numbers of men into the watershed, whose wastes must be prevented from reaching the river. It will be necessary to establish camps at various places, and these camps must be supplied with water, must be drained, must be

provided with bathing and laundry facilities and latrines, and in all respects must be under constant competent sanitary inspection and control far more stringent than, under ordinary conditions, is necessary. It is fortunate that a number of sites for such camps are available, at least 500 feet away from the river, on benches, where the soil, largely gravel, is dry and porous, and hence easily drained and entirely suitable for latrines. Two camps may easily be established outside the watershed; one below the intake, and one near the power house and just over the divide, within the drainage area of the Snoqualmie; and between these two points are the several sites above mentioned, on not more than two of which should camps be established.

At the several camps the necessary latrines should be board outhouses placed over reasonably deep pits for the reception of the discharges, which, out of abundant caution, should be disinfected by the application of milk of lime, made from freshly slaked lime, and kept protected from contact with the air. This should be prepared as often as twice per week, since with age it loses in causticity and germicidal power. As the pits become nearly filled, the filling should be completed with clean soil, and new ones should be dug. Between camps, other latrines should be established at intervals of a few hundred feet, and portable privies may be used, which frequently should be cleaned out and disinfected.

Rules relating to the use of these conveniences and absolutely prohibiting the discharge of human wastes elsewhere within the watershed should be enforced with great strictness and under penalty of dismissal. It will be necessary for the future needs of the section hands and others who will constantly be employed, and of the wreckers who may be brought in from time to time as one or another cause and occasion require, to establish privies at reasonable intervals; but for the last-mentioned a portable privy carried on the train, with watertight box or tank, would be preferable. Absolute prohibition of bathing and laundry work in the river must be emphasized.

In order that the stretch between the intake and the power house shall receive the minimum possible amount of human wastes, it is recommended that, while trains are in the valley, all closets be kept locked and that no stops be made except in emer-

gencies, and that no station or round house be established between those points, even with the consent of the city of Seattle by ordinance, so long as the intake of the public water supply shall be below the present power house. Therefore we recommend the amendment of paragraph 2 of Section 2 of the ordinance granting the right-of-way, by striking out the words, " without the consent of the city of Seattle first having been granted by ordinance," and, further, by making the prohibition a permanent restriction in the deed.

For the most complete safeguarding of the water it is advised that, inasmuch as the soil between the location of the line and the river is frequently impermeable, and where made up of loose stone is devoid of the qualities necessary for slow filtration, the roadbed be trenched wherever necessary or advisable, the trenches being filled with gravel and sand, and that dikes be constructed alongside the trenches wherever necessary or advisable.

The necessary bridges should have steel decks, be ballasted with gravel and sand, and be provided with means for drainage, and the water drained off should be conducted to points at least 50 feet from the river bank on each side, and discharged over appropriate areas or into gravel pits.

During construction the entire area affected should be under the unhampered supervision and control of a competent sanitary engineer appointed by the city of Seattle and approved by the state board of health. He should be empowered to employ, with the approval of the state board of health, as many inspectors to act as sanitary police as the state board may deem to be reasonable, and he and they should be given all of the powers of special police. He should be required to employ one or more registered physicians as medical inspectors, who should examine and report to the board of health of the city of Seattle upon all cases of illness, and cause the immediate removal from the watershed of all persons found to be sick of infective disease.

We recommend, therefore, the amendment of paragraphs 3 and 5 of Section 2 of the ordinance granting the right-of-way, so as to provide for these measures of sanitary protection.

After construction and during operation, so long as water shall be taken from any point below the present power house, the road-

bed should be under the constant supervision and control of a competent sanitary inspector appointed by the city of Seattle with the approval of the state board of health, and the section hands should be required to remove and properly to dispose of such obvious polluting material as may be discovered.

We feel that we should be remiss in our duty as sanitarians, although the matter is one beyond the scope of our employment, were we to neglect to call attention to the necessity of protecting the water supply of the city from possible dangerous pollution of far greater importance than any likely to be caused by the operation of a properly constructed and efficiently guarded railway.

The selection of the Cedar River watershed as a source of water supply was an eminently discriminating and wise act, inasmuch as Cedar Lake and the entire watershed are capable of yielding an abundant supply of pure, soft water. Especially commendable are the steps which have been taken to secure ownership by the city of the banks of Cedar River and Taylor Creek. But the city is apparently unaware of the fact that in using the water of an only partially protected running stream, without storage, it is exposing itself to the danger of a possible outbreak of typhoid fever or other water-borne infective disease. Contrary to common belief, founded on a mistake made by a commission who studied the subject of pollution of streams before the present methods of scientific examination were devised, the water of a rapidly moving stream does not lose its dangerous properties in a run of a few miles after it has received a specific contamination, and it is especially dangerous when this specific pollution has been discharged directly into it or has been washed into it before the action of sunlight and other agencies have destroyed the contained disease germs.

In the course of our examination, fishermen were observed here and there along the banks of the river, and in the woods near the stream were occasional evidences of occupation by camping parties. The danger of wholesale infection from the chance discharges of a single one of such trespassers is, indeed, slight; but it is a real danger, nevertheless, and when unrestricted access to the river is permitted, it becomes multiplied. We are informed that the city is taking steps looking to the abatement of local nuisances within the watershed, but we feel that it is not doing

enough, and will not do enough, until fishermen and all others who have no real business along the city's water supply, or who are not under sanitary supervision and control, are warned off and dealt with as trespassers. Better yet would be the construction of a large impounding reservoir, between Cedar Lake and the power house, as proposed by the city engineer, and the bringing down of the water in mains from that neighborhood, thus gaining the advantage of a stored water.

Respectfully submitted,

A. C. ABBOTT.
CHARLES HARRINGTON.
WILLIAM T. SEDGWICK.

August 11, 1906.

APPENDIX C.

Report to the State Board of Health of Washington upon the Sanitary Aspects of a Grant of Right-of-way by the City of Seattle for a Railroad alongside the Stream from which that City derives its Public Water Supply.

BY JOHN R. FREEMAN, CONSULTING ENGINEER.

1. The question is: May the city of Seattle, with due regard to the public health, grant a right-of-way to the railroad in close proximity to the river above the city's intake for a distance of 10 miles, through lands acquired by the city for the protection of its water supply; particularly in view of the facts that this river flows rapidly and that there is no detention reservoir of size large enough to detain the water a sufficient time to permit germs of typhoid to die, and no filtration works to remove them?

2. My answer is that this right-of-way may be prudently granted if proper safeguards are provided, in rigorously caring for the construction camps, in moving the railroad location somewhat farther back from the river at certain points, in carefully designing culverts, bridges, and ditches, and by providing other safeguards to be described later in detail, and all of which I believe are entirely feasible.

3. The conditions surrounding the water supply of Seattle are, in respect to detention reservoirs, materially different from those at nearly all important cities that use surface water and have railroads, highways, and villages within their watersheds and retain a low typhoid death-rate.

4. A detention reservoir, in which water from the flowing stream must be stored for a month or more before passing into the distribution pipes, is one of the greatest of all safeguards in a surface water supply, and to cite the absence of injurious effects from railroads in watersheds from which the water is stored is mis-

leading as a precedent for Seattle in the proposed location of this railroad.

5. Seattle's water supply is in many ways one of unusual excellence; it is of a very remarkable transparency and freedom from color, and therein is probably not excelled by any large water supply in America and is equaled by very few. It is, in fact, mainly water flowing from springs.

In its selection and method of first development, excellent judgment and engineering skill are shown. Its few shortcomings are mainly those incident to newness and rapid growth and are such as doubtless will be remedied as the city grows, and as fast as the engineer is given the means. I learn that the city engineer has already outlined plans for its improvement, and I doubt not that this Cedar River source can be so improved and developed as to give to more than fivefold your present population one of the finest water supplies in the world. Plainly its purity should be jealously guarded.

6. The fundamental facts on which the answers to the present main question turn are the following:

7. If a single discharge from the bowels (or from the urine) of a person in the early or "walking" stages or the convalescent stages of typhoid fever falls into, or is soon washed into, any tributary of a flowing stream so that it reaches the distribution pipes of a city within a period of two or three weeks, the thousands or millions of the germs in this one pollution may become so scattered and diffused as to enter many households, and possibly finding lodgment in the intestines of those persons whose vitality or power of resistance is low, may bring disease to a hundred and death to a score or more of citizens.

8. The second important fact is, running water does not completely purify itself from disease germs. The three safeguards opposed to the above are:

9. *First*, that the chance is very rare of perfect connection of all the necessary links in the chain of circumstances between the dropping of the pollution and its seeds of disease being sown in the human system.

10. *Second*, that nature has a wonderful process of purification in natural filtration of polluted water by the wash from such material slowly through moderate depths of sand.

11. *Third*, that after a period of two or three weeks of immersion in stream or pond, most of the disease germs die, and that for most kinds of bacteria, sunlight is a great germicide. The coolness of this spring water, its running and aëration as it flows in this turbulent stream, all tend toward safety. The precise period of detention necessary for safety, the full list of water-borne diseases (which certainly comprises typhoid, dysentery, and cholera), and the life-history of these germs, present important problems not yet fully worked out by pathologists and bacteriologists, but we may believe the main facts stated above as proved beyond all doubt or question.

12. It appears well proved, also, that some kinds of disease germs survive drying and transportation in dust, but the greatest danger to a drinking-water supply lies in the water-borne germ, less than two or three weeks old, from the bowel discharge of a human being suffering with typhoid.

Lest some timid person be unnecessarily alarmed at the possibility, by not giving due regard to the probability, I venture a comparison with Providence, R. I., an old, wealthy, and cultivated city of substantially the same size as Seattle. It has for many years taken its water directly from the flowing stream into distributing reservoirs of moderate size, presenting only three or four days' detention, and not until within the past year have its filtration works been completed. The number of inhabitants per square mile on this Providence watershed is 315, which is nearly 100 times as great as on the Cedar River watershed of Seattle; and railroad lines with frequent local trains pass along the porous, sandy margin of its river, without thought of special protection or closing of closets, for distance aggregating more than 10 miles and with 7 bridge crossings. Its last typhoid epidemic was about seventeen years ago. This was traced to a case of typhoid on the watershed, but I have not the details at hand.

On the other hand, the possibilities of the number of cases for which one or a very few sick men can sow the seed, have been shown in a remarkable way at Plymouth, Pa.; Waterville, Me.; Windsor, Vt.; New Haven, Conn.; Ithaca, N. Y.; Chelmsford, Mass.; and elsewhere.

13. These facts have come to be understood and fully proved

only during the past ten to twenty years, through the profound and patient researches of a few small groups of bacteriologists, pathologists, and engineers, and unfortunately have not all of them yet become widely diffused as matters of common knowledge.

14. This is particularly true as regards the danger that may lurk even in the transparent, attractive water of a pure mountain stream that has become accidentally polluted.

DANGERS IN WATER SUPPLIES FROM RUNNING STREAMS WITHOUT DETENTION OR FILTRATION.

15. Years ago, before the recent science of bacteriology was born, a commission of English sanitarians, working from the chemist's point of view, was led to report that a flowing river did tend to purify itself and that its impurities became oxidized.

This is to some extent doubtless true. I doubt not that the water from Cedar Lake, with its many slowly decaying trees, stumps, logs, and weeds, is improved as it tumbles over its steep course of 10 miles to the intake, and that any deleterious effect of the jams of dead logs and tree tops along the stream is thereby lessened. Bad odors from decaying organic or vegetable material are shaken out and oxidation is promoted in water running over such a course.

The half-truth of stream purification became widely circulated and to-day continues to do harm, while 10 times over it has been proved that typhoid epidemics are so carried, and that from a single case along the tributary 100 or 1 000 citizens farther down the line may suffer.

16. It has been found by later studies that water that has been held long in storage is far safer than running water as a source of domestic supply, and the large new supplies of Boston and New York, for example, are being developed with reliance upon this principle of detention for protection against the unavoidable minor pollutions.

Other cities where detention reservoirs are impracticable, for example, Philadelphia, Pittsburg, and Providence, are now constructing great filter plants. So strong is the teaching of recent science and practice concerning the economic value of this safe-

guard that I venture the prediction that Seattle will ultimately, perhaps twenty years hence, come to filtration, unless later surveys shall demonstrate the feasibility of a large detention reservoir, or shall show that sufficient water can be taken by infiltration galleries or large wells directly from the remarkable series of springs which enter the river a few miles up stream from the intake.

For there are various possible sources of pollution already existing in this watershed, such as may produce typhoid, and while some are in process of remedy, others will continue or possibly increase during the many years of lumbering, regardless of whether the St. Paul road comes in or not; indeed, the beauty and attractiveness of this region will tend more and more as time goes on to bring sportsmen, fishermen, campers, and strollers into this watershed.

THE CITY'S WATERSHED.

17. It is only five years since the city of Seattle abandoned its unsatisfactory Lake Washington source and went back about 25 miles into the forests and foothills of the Cascade Mountains and built an intake and diversion dam on the Cedar River, at about 550 feet elevation above sea level, and from this point to the city constructed a wood-stave pipe hooped with iron, 42 inches in diameter. The diversion dam raised the river but little more than 15 feet and flowed back for so short a distance and so narrow a width that the time of detention in the pond thus formed is hardly more than two or three hours, with the mean annual rate of river flow, and not more than half a day at the time of minimum flow.

The city engineer gives the following data:

The city now takes out about 23 000 000 gallons daily, equivalent to about 35 cubic feet per second.

The population supplied, including certain suburban districts, is nearly 200 000.

The present per capita consumption is thus about 115 gallons daily.

The smallest flow of the river at the intake has been found in October, and in the year 1904 amounted to 154 cubic feet per second.

This minimum flow is 4.4 times the average quantity now drawn by the city.

In years of smaller rainfall a smaller river flow may be expected, but just how small cannot be stated from the data thus far collected, which are very scant.

The total watershed area above the intake is at least 139 square miles and may possibly be 145¾ square miles.

This is made up of two areas of different characteristics, although both are heavily timbered. The upper area is more within the mountains than the lower, and comprises a little more than half of the whole, its area tributary to the proposed future high dam being 75 square miles. All of this upper watershed is more than 1 500 feet above sea level and is nearly surrounded by mountains, which increase its average rainfall above that observed in the rain gage at the lake; so that this upper half of the drainage area received more than double the depth of rain that falls on the lower half of the watershed.

The record of 1904 gave for the total annual rainfall at Cedar Lake, at an elevation of about 1 530 feet, 94.4 inches.

The total inches of rainfall during the year 1904 at the intake at an elevation of about 550 feet above the sea was 48.6 inches.

When the whole area of 145 square miles is considered, it appears that the watershed is being rather slowly logged off, so that ten or perhaps twenty years may elapse before the lumber camps will be withdrawn.

The ground in those portions not yet logged is covered with a spongelike humus of decaying vegetation, probably 6 inches deep, which absorbs and restrains the rainfall from rapid run-off, but the fires that appear inseparable from lumbering as now conducted destroy this humus and leave the ground almost bare and sterile.

Cedar Lake for the upper portion, and the vast gravel deposits for the lower portion, will, however, continue to regulate the run-off from the watershed sufficiently for the city's purpose.

The city has already purchased about one tenth of the entire watershed, this being confined mainly to lands bordering on the streams and the lake. These purchases are in some cases subject to mineral rights and the possibility of future coal mines, and in

some cases a right-of-way for future possible branch railroad lines has been reserved.

The city proposes to purchase additional areas as fast as these are logged off, and has arranged with the general government to have certain of the lands not yet sold withdrawn from sale, so that ultimately the city will own substantially its entire watershed.

It is of interest to briefly review the conditions of yield and storage for the purpose of learning if the intake at the water works could be moved up-stream.

The present temporary dam at the outlet of Cedar Lake gives at elevation 1 530 feet above sea level a storage reservoir of 1 300 acres area and 746 000 000 cubic feet capacity. A most excellent dam site that exists a mile or more farther down the stream will permit a high dam to be constructed, raising the level of the lake 60 feet, or to an elevation of 1 590 above sea, giving a storage reservoir of more than 6 times the present volume, or of 1 850 acres, and 4 835 000 000 cubic feet capacity.

This is equivalent to 36 000 000 000 gallons of storage, or half a year's supply for 2 000 000 people, without rain meanwhile.

Before one can state with certainty just how great a constant uniform draft this watershed can be made to supply, an extended study must be made of all Puget Sound rainfall records, and more observations must be had upon the rainfall and evaporation within this mountain region; and there may be remote possibilities of some escape by percolation through old channels filled with porous glacial deposits.

As a rough preliminary figure we can safely reckon that these two watersheds above the city's present intake will be sufficient for all reasonable uses of a population somewhere from 5 to 10 times as great as Seattle now possesses.

The lower half of the watershed, or that immediately up-stream from the intake, is said to be different from the upper in geological character, consisting mainly of a vast deposit of porous gravel, presumably an outwash plain from the mountains, or of glacial origin.

A comparison of the measured flow of the river near the intake with the flow at the outlet of Cedar Lake also brings out the characteristic difference of these watersheds.

While the natural yield from the upper watershed is said to fall to a minimum of about 30 cubic feet per second in August, the minimum flow at the intake dam is not reached ordinarily until October, and in 1904 was found to be 154 cubic feet per second, thus showing a yield from the lower 70 square miles at time of minimum flow more than 4 times as great as from the upper 75 square miles. Plainly the cause of this is the absorption of the winter's rains by the porous gravel deposit of the lower watershed to be stored and slowly given out by percolation to the many large springs near the bottom of the valley. These vast gravel deposits thus take the place of a storage reservoir for the lower watershed and increase its available yield.

18. It will be seen from the foregoing that to seek to avoid pollution by extending the city's intake pipe back to the power house, and thus virtually to the lake, would throw away nearly half of the available watershed area, and an area from which the water is rendered particularly transparent and pure by reason of its natural filtration. All of this watershed will be needed at some future time.

The higher dam would have to be built much earlier if the city's intake were extended farther up the stream, for the minimum yield from the upper watershed is stated to be, under present conditions, only 30 cubic feet per second, while the city to-day is using 35 cubic feet per second.

In view of the fact that the normal minimum yield at the present intake is 154 cubic feet per second, or more than 4 times as great as the present draft by the city, it will be possible to defer the expensive high dam for a number of years by continuing to draw largely from the lower watershed.

19. As the demand for power from the municipal power plant increases it will become more important to have a larger storage reservoir near the present intake than that which now exists.

The demand for power varies greatly at different hours of the day, but the delivery of the aqueduct to the city's reservoirs should be nearly constant. Wherefore an equalizing reservoir near the intake to the aqueduct will, at some future time, become necessary.

DETAILS OF PROPOSED RAILROAD LOCATION.

20. Coming now more into the details of the problem at hand, we find that the railroad, after running many trial lines, has finally staked out a line of location closely following the river for about 10 miles and twice crossing it, and also crossing the large tributary of Taylor Creek. This line runs in some places as close to the water's edge as the steep slope of the high embankment will permit, or so that the water would wash the foot of the steep slope, and riprap be required to hold it, but in general the center line will be nearly 100 feet distant from the water's edge, and for perhaps one fourth of the entire distance will be several hundred feet distant.

A view of the plan, showing the distance between the center line and the water's edge, does not tell the whole story of proximity unless one takes account of the width of roadbed and the width of the steep sloping embankment and of the somewhat nearer water line in time of flood.

21. The formation along the river near the desired location is mainly a vast glacial deposit, showing broad, deep terraces of gravel, for the up-stream 5 miles, but with apparently an increasing amount of bowlders and angular stones for the down-stream portion, so that as far as can now be seen before the ground has been cleared and burned, there will be a very scant bed of sand or fine gravel suitable for natural filtration of the wash from the roadbed along perhaps 2 miles of the line.

Within a distance of 2 or 3 miles up-stream from the intake are many flowing springs breaking out from under the terrace near the foot of the proposed railroad embankment, and the natural surface at the railroad center line is in many places moist, making it probable that when the railroad ditches are cut water will stand or flow continuously in the ditch beside the track at the foot of the inner slope.

22. It is plain from tramping along this railroad location line as now revised that an earnest effort has been made by the locating engineers to keep it farther away from the water than would be the custom under ordinary conditions, and it is plain that increased cost is already incurred in lessening the length of roadbed on

embankment sloping directly to the river, by moving the line farther back so that a considerable portion of the roadbed is in a cut.

23. But it is also plain that the line can, at somewhat further increase of cost, be pushed still further away from the river, and that in many places more of the roadbed can be made in shallow cut, so that there will be a natural earth dike between the roadbed and the river through which the natural drainage and rainwash will filter.

24. I am convinced that it is entirely reasonable for the city, as a condition of granting this right-of-way, to insist that the railroad be pushed back from the water to the very limit, and I find that the extra excavation thereby required will be mainly in gravel of loose, easy character, with some loose rock, but with little or no ledge, and the extra cost not at all exorbitant, so far as can be judged from the surface as now seen prior to clearing.

25. Many other precautions and safeguards not found in ordinary railroad construction should also be made a matter of definite agreement, competent inspection, and absolute enforcement, beyond the terms as they stand to-day in the ordinance granting the right-of-way. These will be described more in detail in the following pages.

In part it should be required that a dike of sand or gravel, say at least 3 feet high by 4 feet top width, be built and forever maintained between the roadbed and the river at all places where this is on the embankment.

Preference should everywhere be given to a roadbed in cut, so as to secure a natural dike, and, in brief, the most complete precautions should be taken regardless of expense, that any rainwash or polluting material falling on the roadbed will be safely filtered before reaching the flowing stream.

Although the chance of infection is small and remote, it is nevertheless possible and certain, and we may well remember the instance of Plymouth, Pa., for example, where it appears to have been proved that more than 1 000 cases of typhoid, with 114 deaths, resulted from the dejecta of a typhoid patient being thrown on frozen ground on the banks of a stream in a watershed that was almost uninhabited.

REASONABLENESS OF CEDAR RIVER LOCATION WITH SAFEGUARDS GUARANTEED.

First having a guaranty of the safeguards which can readily be provided and which can surely be enforced, I am led to conclude that the city of Seattle may prudently grant the desired right-of-way and that it would be unreasonable to withhold it, because of the waste in construction and operation that the best possible alternative railroad location involves, and for all of which waste the commercial interests of Seattle would ultimately have to help pay.

The risks in sanitation that will remain from the presence of the railroad after the prescribed safeguards are rigorously provided will, I believe, be of the microscopic and academic character that we continually have to accept; indeed, it can be figured out that the chance of pollution from the railroad after providing reasonable safeguards will not be one tenth as great as from other sources of possible pollution in lumber camps, sawmill settlements, strollers along the stream and in the branch railroad, all of which exist to-day and some of which will continue to exist indefinitely, and which, taken all together, are, after all, small in proportion to those that are found along the water supplies of many cities without serious epidemics.

Those fond of figures may be interested in the following computation:

Suppose 1 000 different passengers per day to pass through the Cedar River watershed on the St. Paul road; this is 365 000 per year. Health statistics of Massachusetts (the most complete in the United States) show 1.24 cases of typhoid per 1 000 inhabitants per year. Convalescents and those who have the disease in a mild form, in the first week or two of the disease, may travel. We can at most assume that 450 out of all these 365 000 passengers would have typhoid at some time during the year. Calling the duration of those stages of the disease within which one could travel a month, or one twelfth of a year, we can expect only 37 persons actually in the infectious stages will travel over the road during the year.

If these have so many as 4 stools per day, the chance is that

in the twenty minutes (or one-seventy-second of a day) occupied by ordinary trains passing through the watershed, these 37 cases would produce: Thirty-seven cases multiplied by 4 stools, divided by 72, equals 2 stools per year on track; or the probability is that only 2 discharges per year of excreta from typhoid patients are likely to be dropped on this entire 10 miles of roadbed from passengers.

When we consider that one of the residents of a lumber camp sick with typhoid may have an average of say 2 stools per day (we have figured twice this for the passengers), or say at least 50 stools during his entire illness, this is 25 times as many as we figure out as likely to come from all the passengers in a year.

With 500 persons resident in the watershed, the probability is of only .62 cases of typhoid per year among them, and, of course, most of these residents are remote from the stream.

Figuring it in another form, and assuming the domicile in as close proximity to the stream as the track: A resident population of

$$\frac{2 \times 1\,000}{50 \times 1.24} = 32$$

persons would produce the same chance of infection that will be presented by 1 000 passengers per day on the trains.

26. I am told that the best alternative railroad location outside of the watershed or not alongside the city's source of water supply will require from 5 to 7 miles greater distance and necessitate a ruling gradient 0.25 per cent. steeper eastward for nearly 20 miles, approaching the mountain division, adding that much to the distance over which helper engines must run; and that, in addition to the greater length, sharper curves, which tend to limit speed, must be used, and that much more expensive trestles and high embankments must be built, and that some adverse gradient westward would also have to be incurred.

27. With the desired line down Cedar River valley, a continuous grade of eight-tenths of 1 per cent. can be secured and the curves need nowhere be sharper than 3 degrees, permitting high-speed passenger service with outer rail elevation adapted also for low-speed freight, and the lay of the land, its slopes and stream crossing nowhere invite slides or washouts.

POSSIBLE DANGERS TO BE GUARDED AGAINST.

28. The construction of this 10 miles of railroad alongside the city's water source introduces the following specific dangers to be guarded against:

(*a*) For about a year's duration construction gangs aggregating about 500 men will be employed along this 10 miles of river, thereby not only doubling the present total population, but placing all of these new men very near to the main stream. There will also be many camp followers and tramps.

(*b*) At the foot of the steeper eastward grade, near the city's power house, a station for helper locomotives will be established, with a round house and a few residences, which will increase as the business of the railroad grows. It is feasible to locate all of these buildings so that although located within 200 feet of the river their drainage can pass down an ancient channel into another stream, because of the very peculiar lay of the land at this point. But the bringing of this additional population brings more persons who will fish, hunt, or stroll along the nearby stream and who may chance to some time thoughtlessly pollute it.

(*c*) After the road reaches the operating stage, the passenger trains and freight trains will continually carry more and more, and with human nature as it is there will always be the chance of dangerous pollution dropped on the roadbed by those in the early stage of typhoid, dysentery, or other disease, in spite of the rules to lock the toilet rooms during the one-third or one-half hour occupied by a train in passing.

Freight trains and sometimes passenger trains will be detained on the long siding midway.

(*d*) From 6 to 10 section men will be continually engaged in maintenance work on this 10 or 11 miles of track close to the river.

(*e*) By opening up the country and making it more accessible to fishermen and sportsmen and picnickers, a railroad will be the means of bringing more people along the banks of the stream.

(*f*) Tramps, careless and reckless of regulations, will probably, in course of time, follow the railroad line.

(*g*) Double tracking or new bridges, wrecks or other work bringing in large gangs of workmen, are all likely to come in course of time.

29. The safeguards against the possible danger of pollution from the causes just described are all matters of simple care and common sense, all centering around the idea of keeping people out of the watershed or away from the tributary streams so far as possible, and of so placing camps, latrines, sidings, and main roadbed that the rain-wash from any defections or other pollutions will filter through a safe thickness of sand or fine gravel before it reaches the stream, and that all these localities shall be so far removed from the water or so shielded as to practically remove the chance of dust containing any of these germs from being blown into the water.

SANITARY OVERSIGHT REQUIRED.

30. The detailed specifications for much of this work cannot be properly made until the 100-foot right-of-way has been opened up and enough of the cut made to disclose the character of the ground for filtration, and whether flowing springs develop in the hillside districts; therefore the oversight of the whole matter should be placed with some competent sanitary engineer, working under authority of the city of Seattle and the state board of health, who should, from time to time, go over the line as construction progresses, in consultation with the chief engineer of the railroad, to frame such detailed specification as may be demanded by the character of the ground.

The supervising sanitary engineer should have his deputy continually on the ground during the progress of the work in the person of the chief sanitary inspector.

During the year of active construction this chief sanitary inspector will require the services of 3 or 4 deputies to look after the details of sanitation properly. At least one of these should be a physician skilled in the detection of typhoid and who should keep close watch of the health at the several camps. The entire line where work is going on should be patrolled twice daily.

After the construction period is over an inspection should be made at least once a month over the entire length of the railroad line of the St. Paul and also over the present Northern Pacific branch railroad. The sawmill village and the several lumber camps and the shores of the main stream all the way above the

intake should also be inspected once a month by some one trained in sanitary science, and a record made on a carefully prepared blank, giving the conditions found, should be placed on file with the city water department.

31. Three or possibly 4 construction camps will be needed during the building of this 10 or 11 miles. Two of these camps can be located outside of the watershed, one at either end.

There are admirable locations for the 1 or 2 intermediate camps at points where the roadbed is located upon a bench several hundred feet back from the river.

32. Each of these 1 or 2 camps within the watershed should have its water supply piped in for drinking, cooking, and washing, and with hot water also on tap. This camp supply in general should be made more convenient than to visit the river for water. Deep pits should be dug into which all drainage from washing and cooking should be led to slowly filter away. Numerous light wooden privies that can be readily moved should be built and placed over pits, and these should be regularly disinfected by lime and slowly refilled with earth. A barbed wire fence of double strength should separate the camp from the river. Before occupancy the camp ground should be cleared of all trees and underbrush and the space between the camp and the river should also be cleared and burned for half a mile each way along the line so as to remove all cover.

Then with a sufficient number of sanitary inspectors and the prompt discharge of offenders, it will be entirely feasible to make the camp safe, as has been done on recent large work for the city of Boston close beside its water sources, where many foreign laborers were employed.

It should be made a part of the contract between the city and the railroad that any laborer, foreman, or other employee caught transgressing the sanitary rules will be immediately dismissed; and if one or more of the sanitary inspectors be given authority of a constable to arrest any offender against the health ordinance, it will help.

LOCATION OF RAILROAD FARTHER BACK FROM RIVER.

33. A relocation of the railroad line farther back from the river is the first work demanding attention.

To do this important work in the best manner and as a basis for laying out the further safeguards, a new survey map should be made on the scale of 100 feet to the inch, utilizing all present topographic notes and immediately putting surveyors in the field to extend the contours to cover with greater precision all of the ground between the road and the river and to reach up to the top of the terrace.

ENLARGED DETENTION RESERVOIR AT INTAKE.

34. The railroad grade may need to be placed at an elevation perhaps 20 feet higher (more or less) than it has yet been located, where it crosses the intake pond of the city water works, in order that the city may not sacrifice its opportunity to construct more of a detention and equalizing reservoir at the intake. Reference has already been made to its importance at some future time, for equalizing the irregular draft of water for power, so that it may be taken into the water supply conduit at a uniform rate, and whatever can be gained in detention of the water from the rapidly flowing stream before it enters the city's supply will be an advantage.

Surveys and studies on behalf of the city are needed to find out just how far such an enlargement of the present intake pond is feasible. The railroad's line as now surveyed is understood to permit little or no enlargement, and its engineers will naturally be opposed to raising the grade at this point.

Apparently no very good opportunity exists for a sufficient detention at the intake, this being complicated by the fact that the flood flow is many times larger than the city's present rate of draft; but this condition will change somewhat as the city grows and the Cedar Lake storage capacity is largely increased, and the matter is well worth the cost of immediate surveys and studies before the railroad makes the larger reservoir at this point forever impracticable.

CLEARING GROUND BETWEEN THE RAILROAD AND THE RIVER.

35. The trees should be cut, the logs removed, the stumps and dead wood burned, for the entire 100-foot width of right-of-way of the railroad. The ground between the railroad and the river

should all be similarly cleared and kept cleared, the object being to remove all cover and to permit easy inspection from the railroad and the prompt discovery of any trespassers.

The city, for its part, might also completely clear a strip 100 to 200 feet wide on the opposite bank, also for the purpose of removing cover and for making its sanitary patrol easy and efficient.

The value of shade for keeping the water more cool is mainly fanciful and far less than the value of the sun as a germicide. Ease of inspection is one of the greatest of all safeguards.

FENCING.

36. A barbed-wire fence should also be built along the inner boundary of the railroad's land as soon as the work of felling trees, burning and clearing is completed. This fence should be extra strong and tight, its object being to impede access to the water of tramps, railroad section men, or those who may leave the trains in case of accidents or detentions at sidings.

Should it be concluded that it is too much to ask for the maintenance of such a fence over all of this 10 or 11 miles, it should certainly be insisted upon for a strip nearly a mile in length near each construction camp and near the permanent siding.

CULVERTS.

37. Culverts, preferably of cast-iron pipe, of ample size, with tight joints, should be laid safely below frost, and for the entire 100-foot width of the right-of-way, for all small streams, flowing springs, and gulleys that give evidence of stream flow in time of rain.

An effort should everywhere be made to protect these small natural streams that cross under the roadway from any possible rain-wash of polluting material dropped on the railroad right-of-way by passenger, tramp, trainhand, or workman.

SIDE DITCHES AND DRAINS.

38. Where the railroad cut lies through moist ground, so that water percolates into the ditch on the uphill side, forming at times a running stream along the ditch, the ditch should be deepened

about 3 feet or more, according to circumstances, and have a width of at least 2 feet. In the bottom of this trench vitrified drain pipe, not less than 6 inches in diameter, and generally more, according to extent and length of water found, should be laid with open joints, surrounded and covered with coarse gravel for at least 1 foot in depth, and over this filled with fine gravel up to the ordinary form of a railroad side ditch. This drain pipe should be extended a sufficient distance through dry, porous gravel to permit the water thus collected to filter away through a safe distance of not too coarse earth before reaching the river.

39. There are several localities within this 10 miles where, so far as can to-day be seen, the ground will be found so rocky after the humus is burned off that it will perhaps prove unsuitable for filtering material. This is particularly true at several points within 2 or 3 miles of the intake. At such points the rain-wash from pollution dropped on the road ballast might fail of proper detention and purification unless ditches and drains are constructed as described in the preceding paragraph. It may, after further investigation, be found best to carry large drains of the type just described down stream from localities near the intake so that they will discharge below the watershed limits. The fact that the grade of the railroad descends without interruption at the rate of about 40 feet per mile for the entire distance of 10 miles makes drains of this kind feasible.

The details of side-ditches and vitrified pipe drains and the gravel covering them will have to be studied out on the ground after its character has been more fully shown up by clearing off the timber and dead wood, burning off the humus, and making the main cut.

SIDING.

40. Only one side track for passing trains is desired within this 10 miles. An excellent site for this is found on a high bench or terrace of gravel nearly opposite the sawmill village of Barneston. At the site of this siding the railroad line should be crowded against the hill so as to give greatest possible distance from the river. By so doing a distance will intervene that can be regarded as entirely safe.

To provide against possible pollution during the long detention of freight trains here, 3 or 4 small, neat privies should be constructed along the line over pits dug deep in gravel, and the whole properly cared for as part of the regular maintenance work of the section gang.

Here and at all tool houses for the section gangs it may not be amiss to pipe from the small spring on the hillside so as to give a convenient drinking-water place, and to lead the drainage therefrom into a blind drain in the porous gravel.

A location about a mile below Barneston also furnishes a favorable site for one of the construction camps and for a tool house and headquarters for the section gang.

The ordinance should forbid any regular station on the railroad within the watershed.

SECTION GANGS.

41. After the railroad construction is finished and the road is in operation, its maintenance will require the continual services of, say, 1½ section gangs for this 10 miles.

It can doubtless be arranged that only 1 gang will have its headquarters and its tool house within the watershed limits, while the ends are cared for by the gangs domiciled just outside.

Conspicuous notices, in large type, should be placed in all the section tool houses for each of the 3 gangs that work within this watershed, directing attention to the preservation of the purity of the city's water supply. Small, neat privies over deep pits should be maintained, at convenient intervals, for the section gangs along the entire 10 miles of road within the watershed, to the satisfaction of the city's sanitary inspector, and the section men should be instructed to bury, immediately, any polluting material found on the track.

BRIDGES.

42. It is already prescribed in the ordinance that the bridges are to be tight deck bridges. The St. Paul road crosses the main river twice within the watershed and makes an equally important crossing of Taylor Creek, which is also a large, rapidly flowing stream.

It would be almost impracticable to secure by ordinary methods of railroad bridge construction a deck so tight that heavy rain would not wash pollution through it or around the end of its parapet back into the stream.

Special care, therefore, must be given. My recommendation is for a reinforced concrete arch bridge at each of these 3 important crossings, having the top of its arch, say, at least 2 feet below the bottom of the ballast and with a space over the arch filled with moderately coarse porous sand, such as will afford good filtration. The side parapets should be carried up 4 feet above the rail and extended for at least 50 feet into the bank beyond the high water line.

The smaller creeks and the channels that run strong in time of heavy rains should each be the subject of a somewhat similar precaution.

HELPER-ENGINE STATION.

43. Near to the city's electric power station, but just outside the city's watershed, there will be located a small round house for locomotives used to help trains up the heavier eastward grade that begins near this point. The lay of the land here is so peculiar that, although distant but a few hundred feet from Cedar River, all of these buildings can be made to drain outside the watershed, and the only danger is that as business grows and the station becomes larger, men off duty, or members of their families, will stroll along the river and might thoughtlessly pollute it. It will doubtless be sufficient for the city to require the maintenance of an extra strong and tight barbed wire fence along the railroad location here, and to post conspicuous notices asking for thoughtful care in preserving the purity of the water.

ANTI-POLLUTION NOTICES.

44. It will be useful for the city to prepare a large number of conspicuous notices, printed on cloth in very coarse type, briefly asking the coöperation of all who walk along these portions of the river to lend their aid in preserving the purity of the city's drinking water supply, and to nail these to posts and trees all along the line of Cedar River, and also along those creeks and valleys that pass near to the lumber camps.

Such a request for friendly aid will doubtless be as efficient as posting copies of the health ordinances with a description of the penalties.

LOCKING OF PRIVY DOORS ON CARS.

45. Representatives of the railroad have offered the suggestion that the closet doors could be locked during the times that trains are passing over this 10 or 11 miles of track within the city's watershed, and, perhaps relying on this safeguard as sufficient, had not proposed such extensive structural precautions as I have outlined above.

It appears certain to me, after careful consideration of the known facts regarding typhoid and of the epidemics that have been plainly traced to pollution of a flowing stream, that the safety of the citizens of Seattle demands the more certain, although much more expensive, safeguards herein recommended.

The time of crossing the watershed by a passenger train on an up-grade might often be nearly half an hour, and for a freight train the period would be longer, and still longer periods within the watershed are probable in case of detention at the siding waiting for a belated train, or while waiting for a clear track after a wreck.

Persons coming down sick or homeward bound with typhoid or dysentery, or in the early and unrecognized, but infectious, stages may be among the passengers, and it is too much to expect or to require that the door would always be kept locked against urgent need.

Detachable pans under the car closet may possibly, at some future time, come into use, as is now being done on some German railroads, but it is too much to expect that their use could be relied on on all sorts of cars on this 10-mile run between unimportant stations out in the woods. The only safe way is to safeguard the roadbed construction on the theory that closets will often be left unlocked, and then add to the safety by keeping them closed as much as can properly be done.

REMEDY OF EXISTING POSSIBLE SOURCES OF POLLUTION.

46. My own examination was confined to the proposed St. Paul railroad line and the territory adjacent thereto.

Whatever chances of pollution may exist to-day, these are plainly no justification for an increase in the chance of pollution, and therefore I did not consider that the present question required me to seek out the various settlements in the watershed or to inspect the lumber camps, but at Barneston our party spent the night, and thus had opportunity to note existing conditions.

I am told that there are now about 500 persons resident within this watershed. This is a remarkably small number per square mile as city watersheds go, and would not give rise to serious apprehension except for the fact that the city takes its water directly from the rapidly flowing stream and that a part of this population, at least, resides in undesirable proximity to rapidly flowing tributaries.

At Barneston the village of the Japanese sawmill laborers, in time of heavy rains, now drains directly into Cedar River, but I am told that new houses for these laborers are already approaching completion and that present houses and privies will soon be torn down. So in the lumber camps and elsewhere doubtless improvement will be the order of the future, and the chief sanitary inspector that the city employs on this railroad work may, during the year of railroad building, very properly extend the scope of his inquiry and study of improved conditions throughout the watershed.

INVESTIGATIONS FOR IMPROVEMENT OF SUPPLY.

47. With the best sanitary inspection that is practicable a rapidly flowing stream will always present some remote chance of danger, and therefore I am led to earnestly recommend that the city engineer make, in the immediate future, a sufficient reconnaissance both for the enlarged detention reservoir at the intake already mentioned and also for learning just what opportunity there may be of securing a supply sufficient for the present needs of the city from the remarkable series of large cool springs within 2 or 3 miles of the present intake. An inspection of the map of the watershed boundaries gives small hope that these springs will suffice for anything more than a temporary supply, but the present is a good time for reviewing all of these possibilities and for making full and precise measurements that will be very useful in all future studies.

FISHING.

So long as no detention reservoir exists and the water is without filtration, fishing along Cedar River above the city's intake may well be prohibited, not on account of the fishing, but simply as one more means of lessening the chance of a man in the early and unrecognized stages of typhoid strolling along this stream. Even the spit of one coming down with typhoid is said to contain the germs of the disease, and the typhoid bacillus sometimes continues to be found in the urine for several weeks after the patient is so far convalescent as to be walking around.

SWAN LAKE AS A DETENTION RESERVOIR.

A part of the chief engineer's original plans was to provide a period of detention of the Cedar River water in Swan Lake. This lake is reported to have been found containing large quantities of wild fowl guano at its upper end, and it is also stated that the elevation above sea level is somewhat smaller than desirable for economy in size of aqueduct to the higher levels of the city.

In view of the well-known possibilities of danger in taking water from a flowing stream, I venture to suggest that this whole matter of Swan Lake and other possible sites for a detention reservoir should be carefully studied anew.

The expense already incurred by the city in securing a sparsely settled mountain watershed, and in systematically beginning to purchase the fee to the entire area as a means of excluding pollution, the excellence of this gathering ground, its sufficiency for the city for many years in the future, the great importance of a supply of water pure beyond suspicion as an asset in encouraging the city's growth, all concur to make this question of avoiding any new source of pollution paramount.

The one death per thousand inhabitants per year from water-borne typhoid may as easily be the foremost citizen as the humblest.

Respectfully submitted,

JOHN R. FREEMAN,

Consulting Hydraulic Engineer.

AUGUST, 1906.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, November 14, 1906.

President William T. Sedgwick in the chair.

Before the members took seats, a toast was drunk in silence to the memory of Freeman Clarke Coffin, whose funeral fell on the day of the meeting.

The following members and guests were in attendance:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, J. E. Beals, F. D. Berry, J. M. Birmingham, J. W. Blackmer, E. C. Brooks, G. A. P. Bucknam, George Cassell, C. E. Childs, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, M. J. Doyle, C. R. Felton, Desmond FitzGerald, A. N. French, F. L. Fuller, J. C. Gilbert, A. S. Glover, J. O. Hall, L. M. Hastings, V. C. Hastings, T. G. Hazard, Jr., D. A. Heffernan, H. G. Holden, J. L. Howard, Willard Kent, G. A. Kimball, G. A. King, Morris Knowles, E. E. Lochridge, Thomas McKenzie, Hugh McLean, H. V. Macksey, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, H. A. Miller, Wm. Naylor, F. L. Northrop, J. H. Perkins, W. W. Robertson, E. M. Shedd, G. A. Stacy, J. A. Tilden, A. Townsend, R. J. Thomas, H. L. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, C. K. Walker, J. C. Whitney, F. E. Winsor, G. E. Winslow. — 61.

Honorary Members.

W. T. Sedgwick, F. W. Shepperd. — 2.

Associates.

Ashton Valve Company, by C. W. Houghton; Harold L. Bond & Co., by Harold L. Bond; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, F. A. Smith, W. A. Hersey, H. V. Macksey; International Steam Pump Company, by Sam'l Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by O. B. Mueller and Geo. A. Caldwell; National Meter Company, by Chas. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Perrin, Seamans & Co., by Chas. E. Godfrey; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Platt Iron Works Company, by F. H. Hayes; Thomson Meter Company, by S. D. Higley and E. M. Shedd; Union Water Meter Company, by Edw. F. King and F. L. Northrop; United States Cast Iron Pipe

and Foundry Company, by F. W. Nevins; R. D. Wood & Co., by Wm. F. Woodburn; Water Works Equipment Company, by W. H. Van Winkle. —26.

GUESTS.

George H. Finneran, Thomas A. Lennon, Boston, Mass.; E. L. Harvell and John H. Burke, water commissioners, Rockland, Mass.; A. W. Danforth, Reading, Mass.; Dr. Benj. P. Wall, Berkeley, Cal.; Arthur E. Blackmer, superintendent, Plymouth, Mass.; Wm E. Bailey, commissioner, Beverly Mass.; H. O. Brooks, Lowell, Mass. — 9.

[Names counted twice — 6.]

After luncheon had been served, and before the opening of the regular exercises of the afternoon, an informal address of thanks was made by the President, on behalf of a large number of active and associate members of the Association, accompanied by the presentation of a gold watch, duly inscribed, to Mr. Frank E. Merrill, whose services in connection with the annual convention at Fabyans, N. H., were not only untiring and self-sacrificing, but highly appreciated. Mr. Merrill, to whom the presentation came as a complete surprise, made a response accepting the gift with hearty thanks and expressions of satisfaction in the kind feelings which prompted it.

Applications for active membership by the following-named persons, properly endorsed and recommended by the Executive Committee, were presented by the Secretary:

William C. Lounsbury, Superior, Wis., bacteriologist and chemist for the Superior Water Company; Henry A. Symonds, Athol, Mass., superintendent water works; George H. Finneran, Boston, Mass., chief clerk distribution division, Boston Water Department; Andrew S. Corr, Phillipsburg, N. J., inspector of cast-iron pipe for gas and water companies, and water-works materials for various cities and corporations; Hardolph Wasteneys, Brisbane, Australia, chemist to the Brisbane Water Works and director of laboratory; C. P. Nibecker, Pittsburg, Pa., connected with the operation of filter plants for the American Water Works and Guarantee Company; Edgar A. Cate, Everett, Mass., in charge of water income and department accounts; Elton D. Walker, State College, Pa., professor of hydraulic and sanitary engineering, and expert for Pennsylvania State Department of Health.

On motion of Mr. Coggeshall, the Secretary was instructed to cast one ballot in favor of the applicants, and he having so done they were declared regularly elected members of the Association.

The President read the following minute adopted by the Executive Committee and ordered to be presented to the Association for its action:

"It has come to the knowledge of your Executive Committee that the appropriation for the gaging of streams and other investigations of the water resources of the United States by the United States Geological Survey was reduced at the last session of Congress by the large amount of $50 000, this being one fourth of the whole sum previously appropriated. We learn also that some of the congressmen from New England were active in bringing about this reduction. We therefore recommend that the following minute be adopted by the Association and spread upon its records, and that a copy of the same, signed on behalf of the Association by the President and Secretary, be mailed to every member of Congress from New England.

"'The New England Water Works Association has learned with regret that a reduction of $50 000 was made at the last session of Congress in the appropriation in the Sundry Civil Bill for the work of the United States Geological Survey in the gaging of streams and other investigations of the water resources of the United States. The Association believes that this reduction was uncalled for and has already done harm. It desires to place on record its appreciation of the hydrographic work of the United States Geological Survey, and its earnest hope that the members of Congress from New England will exert themselves to see to it that the reduction be not continued beyond the present year. It believes that the industrial progress and the sanitary welfare of the people of New England largely depend upon the conservation and development of their water supplies, and it commends the judicious activity of the United States Geological Survey in making stream measurements, investigating the pollution of interstate rivers, and, in general, in seeking out and making known the water resources, not only of New England, but of the whole country.'"

Mr. Frank L. Fuller moved that the minute as read be accepted and adopted. Carried.

Mr. Robert J. Thomas called attention to the vacancy in the list of nominees for officers for the ensuing year presented by the Nominating Committee, caused by the death of Mr. Freeman C. Coffin, who was named for one of the vice-presidents, and moved that the same committee be authorized and instructed

to make a new nomination to fill the vacancy. The President stated that the constitution does not make definite provision for a contingency of this sort, but if the motion were passed without objection it ought to have all the force of law and the constitution. Adopted.

The President again expressed his great desire that at the meetings of the Association a larger number of practical experience papers should be presented than has been customary in recent years. Speaking upon this subject, he said:

"As many of you know, I have been anxious that we should have at our meetings a greater number of practical papers by the water-works superintendents of New England. We find it easy enough to get learned, scientific papers, and we want these. It has been the glory of this Association that it has had so many such papers, and that some of the most important original articles of the day in water-works science have been read at our meetings and published in our JOURNAL; but for a large majority of our members actual experience papers would be of no less, and perhaps even greater, interest. Your officers, however, have no way of arranging for such papers unless these are volunteered by communications from individual members. If any man is having trouble with any particular problem, and is willing to talk frankly about it, and get advice from his fellow superintendents, let him drop a note to Mr. Kent and say he would like to talk for five minutes or more on such or such a subject. We shall welcome suggestions of that kind, and I am particularly anxious that the coming meetings, if we can arrange them so, shall be devoted largely to such discussions. To-day we have the more scientific and more learned papers, so-called, but we ought to have at about every other meeting practical papers also, dealing with the difficulties that practical men are encountering from day to day. If there is a judicious mixture of the two kinds of papers, the Association will go on to even greater successes than it has attained hitherto, while if it gives itself up wholly to either alone it will surely fail of accomplishing the best results. So we beg any one of you who has in mind any topic he thinks it would be interesting to have discussed, to write to Mr. Kent or to me or to any member of the Executive

Committee, and we will try to arrange for its discussion and see that it goes off well."

The first paper of the afternoon was by Mr. Charles R. Felton, city engineer, Brockton, Mass., and was a "Description of Brockton's New Water Works," illustrated by stereopticon views. Remarks were made in connection with the paper by Mr. Desmond FitzGerald and Mr. Morris Knowles. The second paper was by Mr. L. M. Hastings, city engineer, Cambridge, Mass., entitled "A Study of Some Vital Statistics." This, also, was illustrated, and the discussion was participated in by President Sedgwick, Mr. Desmond FitzGerald, Mr. Morris Knowles, Mr. Frank L. Fuller, Mr. Hiram A. Miller, Mr. Robert J. Thomas, and Mr. Charles R. Felton.

Adjourned.

EXECUTIVE COMMITTEE.

Tremont Temple, 11.30 A.M., November 14, 1906.

Present: President William T. Sedgwick, and John C. Chase, Robert J. Thomas, James L. Tighe, George A. Stacy, Lewis M. Bancroft, Frank E. Merrill, and Willard Kent.

Eight applications were received and the applicants recommended for membership.

Eulogistic remarks were made on the life and character of our late associate, Mr. Freeman C. Coffin, and the committee on nominations of officers of the Association for the coming year were requested to fill the vacancy in the list already issued caused by his death.

The question of place of next annual convention was discussed, and on motion of Mr. Chase, seconded by Mr. Tighe, the subject was referred to the next meeting of the Executive Committee.

On motion of Mr. Stacy, seconded by Mr. Tighe, it was voted:

That the Executive Committee recommend to the Association that the Association express its regret at the action of Congress in reducing the appropriation for the measurement of streams, etc., by the United States Geological Survey.*

Adjourned.

WILLARD KENT, *Secretary.*

* See minute as printed on page 489.

OBITUARY.

William Winslow Burnham died in the Wilmington, N. C., hospital, August 11, 1906, of typhoid fever, after an illness of seven weeks.

Mr. Burnham was born in Biddeford, Me., August 24, 1875, graduating from the Biddeford High School in 1892, and from the sanitary engineering course of the Massachusetts Institute of Technology in 1903. Immediately after graduation he obtained a position in the engineering office of the Massachusetts State Board of Health, which position he resigned June 1, 1904, when he accepted an appointment to the United States Geological Survey, Hydrographic Division. While in this position his work involved the determination of the depth of ground waters over the desert region known as Carson Sink. He was also connected with the Truckee-Carson irrigation project which the government is now constructing in Nevada. In the fall of 1904 he made a survey of the surface and artesian waters of Georgia, which completed his work with the United States Geological Survey.

February 1, 1905, he became the engineer of the Hugh MacRae Company of Wilmington, N. C., with which company he remained until his death.

Mr. Burnham was married, March 6, 1906, to Miss Ella M. Cate, of Malden, Mass.

He was a member of the Boston Society of Civil Engineers. He was elected a member of this Association on September 13, 1905.

Freeman Clarke Coffin, civil engineer, died at his home in West Medford, Mass., on November 11, 1906, after a brief illness.

Mr. Coffin was born in Boston, September 14, 1856, but while he was very young his parents moved to Patten, Me., where he received his early education, and later started in the manufacture of furniture. In 1882 he came to Boston and entered the employment of the Coffin Valve Company, of which his uncle was one of the managers, as a pattern maker, but seeing no opportunity to rise in this work looked for engineering employment, and after two years entered the office of the late M. M. Tidd. Mr. Tidd was at that time probably better known as a water-works designer and builder than any other engineer in New England.

Up to this time Mr. Coffin had had no training or experience in engineering work, and he was then twenty-eight years of age. Nevertheless, in about two years he became Mr. Tidd's principal assistant. He remained with Mr. Tidd about ten years, and in 1894 started in business for himself, making a specialty of water works and sewerage systems. During the twelve years he was in business he constructed many such systems in the United States and Canada, and also acted as expert in a number of water-works valuation cases.

A few years ago he published a valuable handbook entitled "Graphical Solution of Hydraulic Problems."

The high position attained by Mr. Coffin in his profession is too well known by the members of this Association to need amplification here. At the time of his death he was the senior vice-president of the Boston Society of Civil Engineers, and chairman of the Sanitary Section of that society. He was also a member of the American Society of Civil Engineers, and of the Canadian Society of Civil Engineers.

Mr. Coffin had much to do with inaugurating and carrying out a great deal of the most important technical work done by this Association. A brief paper entitled "A Few Notes on Cast-Iron Pipe," presented by him in March, 1900, published in the Journal for September of that year, suggested the preparation by this Association of standard specifications for cast-iron pipe;

as a result a committee was appointed, with Mr. Coffin as chairman, which, after a great deal of work, gave us our present admirable standard specifications. Later, as the result of a brief paper presented by him in January, 1904, a committee on meter rates was appointed, with Mr. Coffin as chairman. For the committee he opened a topical discussion on this subject at the March, 1904, meeting, and submitted progress reports at the 1905 and 1906 conventions. This committee is still in existence.

Mr. Coffin had also presented to the Association a considerable number of papers. Among the most important of them may be mentioned the following:

"Standpipes and Their Design," 1893; "Financial Management of Water Works," 1896; "Friction in Several Pumping Mains," 1896; "Application of Gas, Gasoline, and Oil Engines to Pumping Machinery," 1899; "Covered Reservoirs and their Design," 1900.

He had never held office in this Association, but had just been nominated for one of the vice-presidents for the year 1907. He was elected a member on February 13, 1899.

BOOK REVIEW.

Quasi-Public Corporation Accounting and Management. By John F. J. Mulhall, P.A. Boston: Corporation Publishing Company. Half morocco, $6\frac{1}{4} \times 9\frac{1}{2}$ inches. Pp. 203. Price, $5.00.

This book treats principally of the accounts and other records which should be kept by public-service corporations, including water, gas, electric light, steam heating, telephone, and electric railway companies. Two brief chapters are devoted to the formation of corporations and information relating to stocks and bonds, with examples of stock certificates, bonds, coupons, trust deeds, etc. The remainder of the book is devoted to the forms of accounts, records, etc., needed in the operation of such a corporation.

Water works are first taken up, and are treated at greater length than any of the other kinds of public-service works. This is, however, because many of the forms required are substantially the same for all such systems, and the principles having been once set forth under the head of water works, it would be mere repetition to present them again in detail under each of the other kinds of works.

Copies of all the important forms are given, in most cases illustrated by cuts showing actual forms on reduced scale. Methods of keeping the customers' accounts, as well as the ordinary accounts of the company, are explained. A part of this section of the book was outlined by the author in a paper presented to this Association at its convention in 1905, and is printed in the Journal for December, 1905, page 395.

Quite as important, in many ways, as the financial record of such a company, are the "house-to-house inspection," "on-and-off" and meter records, construction records, etc., which are illustrated in some detail.

The special accounts and records required by the other kinds of public-service works are explained and illustrated in the section devoted to those works. A commendable feature is the inclusion of the form of report required by the Massachusetts Board of Gas and Electric Light Commissioners.

The difficult but very important subject of depreciation is discussed briefly. Tables of annuities, compound interest, and sinking funds are also given.